Fractionally Charged Quasiparticles

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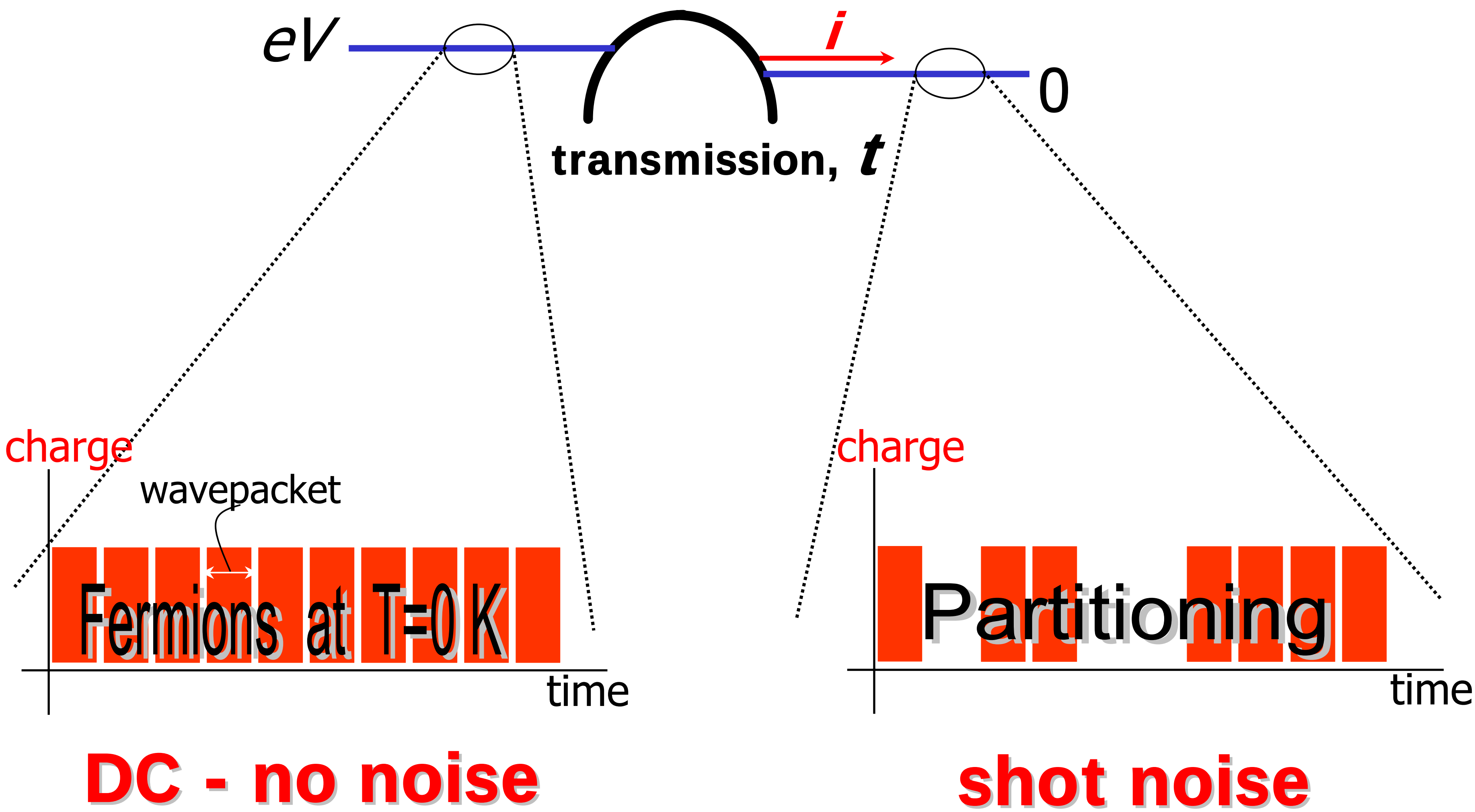
- shot noise measurements and charge determination
- difficulties in the determination of charge
- noise and charge for fractions in higher Landau levels

charge determination *via* partitioning



shot noise - stochastic partitioning

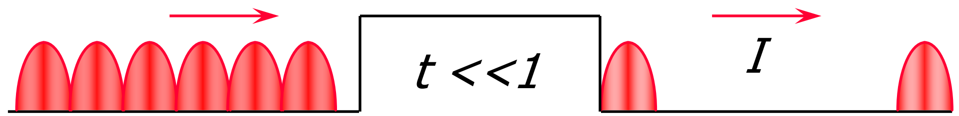
spectral density of current fluctuations $S_i(\nu) \equiv \frac{\langle(\Delta i)^2\rangle_{\Delta\nu}}{\Delta\nu}$ (A^2/Hz)

incoming ordered train transmitted partitioned train

poissonian

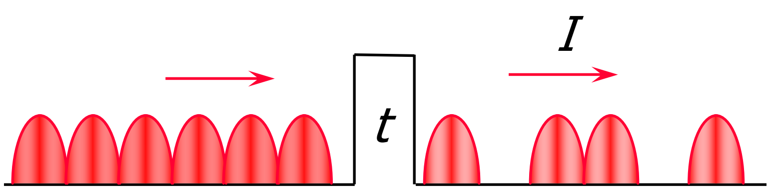
$S = 2qI$

Schottky formula in a vacuum tube



binomial

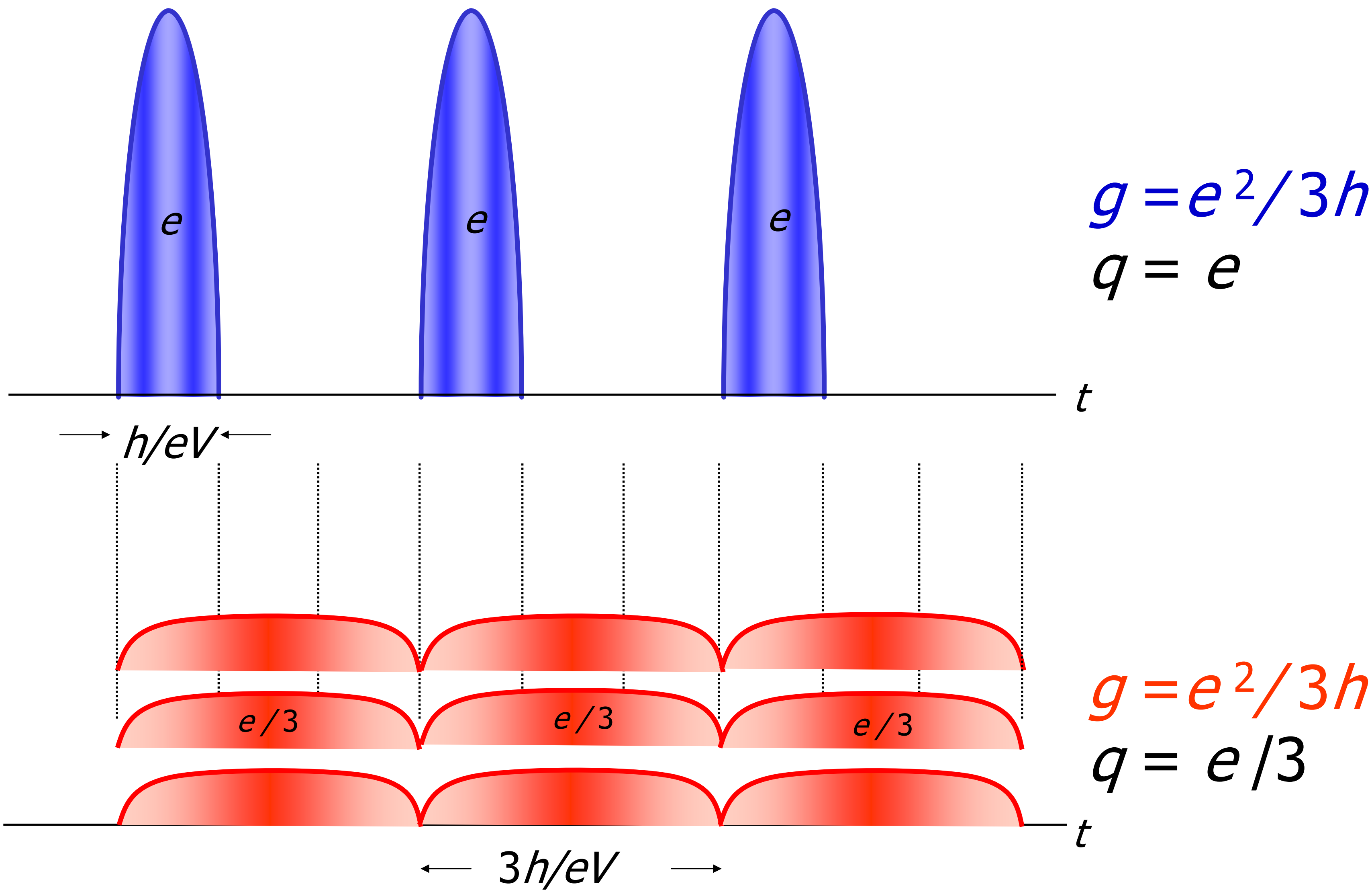
$S = 2qI(1-t)$



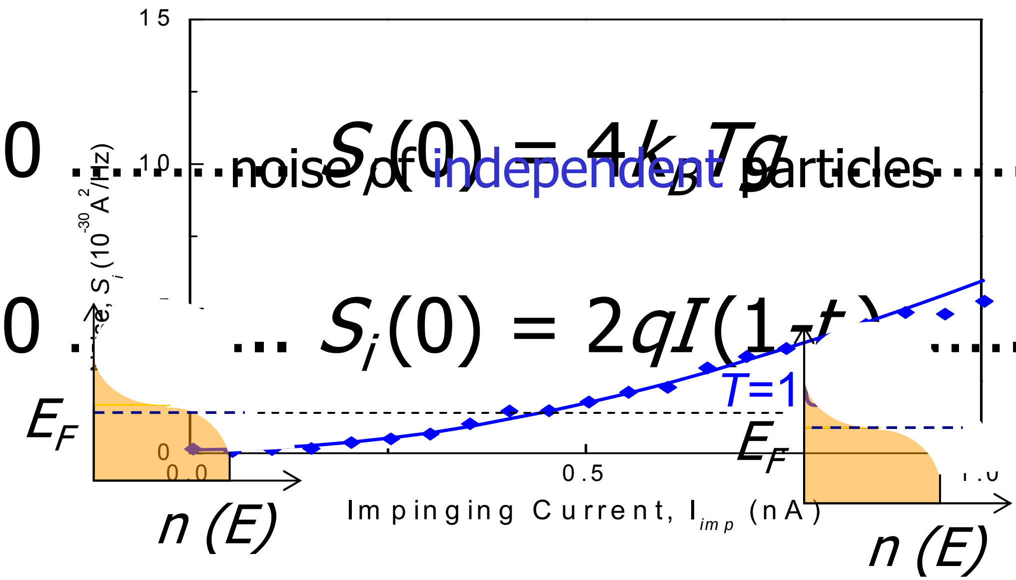
Khlus, 1987

Lesovik, 1989

conductance & shot noise



shot noise at finite temperatures



$V = 0$ .... $S_i(0) = 4k_BTg$ ....thermal

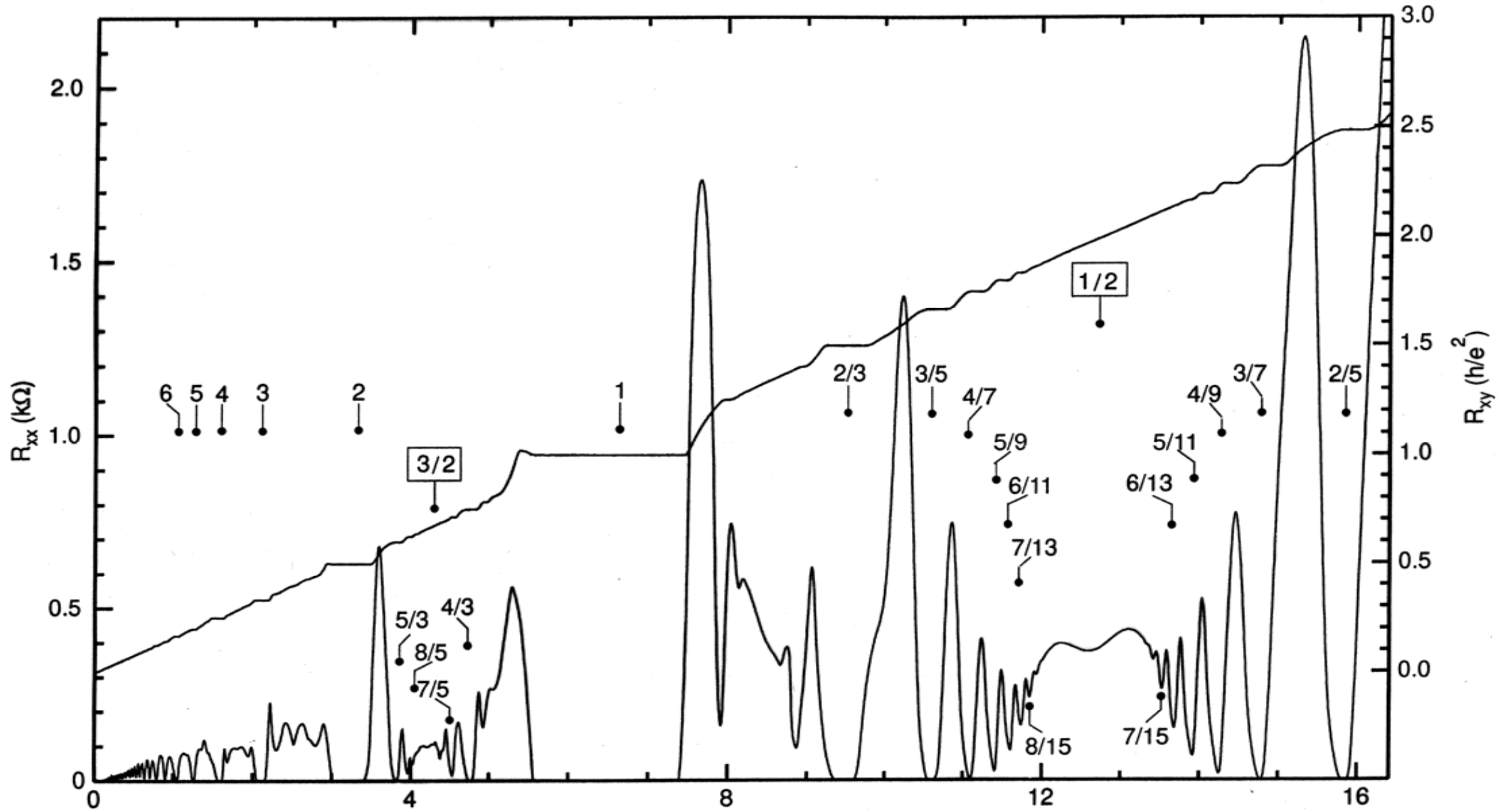
noise of independent particles

$T = 0$ .... $S_i(0) = 2qI(1-t)$ ....shot

$V, T > 0$ ....total

$$S_i(0) = 4k_BTg + 2qI(1-t)\left[\coth\left(\frac{qV}{2k_BT}\right) - \frac{2k_BT}{qV}\right]$$

FQHE



Magnetic Field (T)

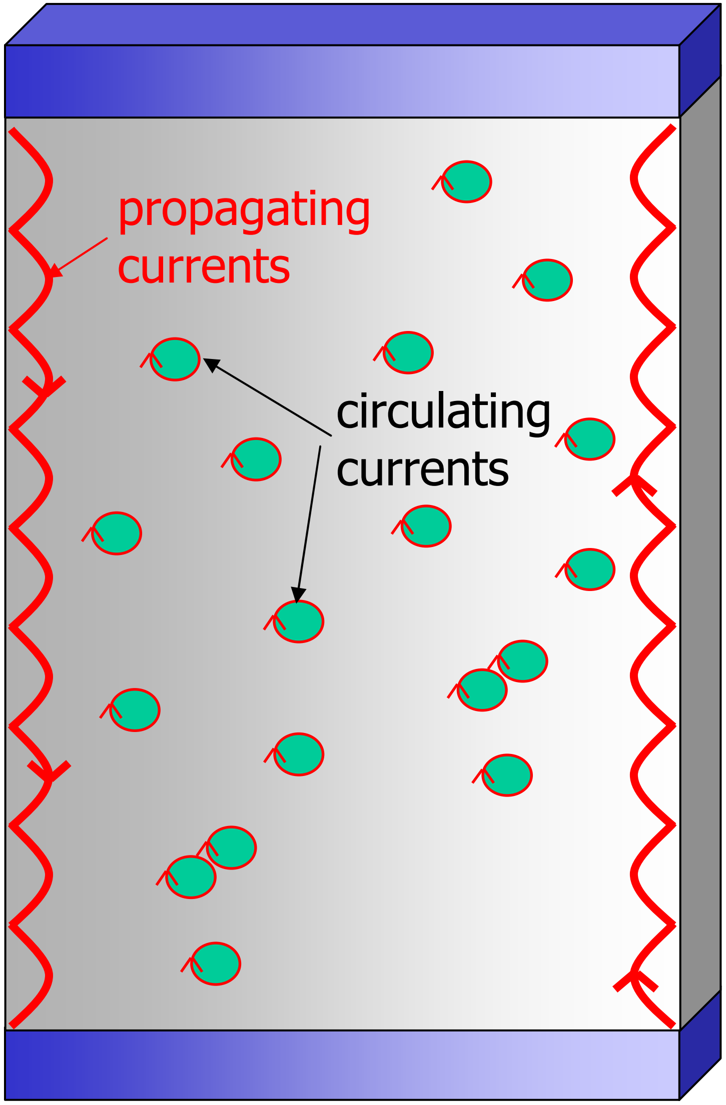
J. Smet, V. Umansky

edge channels in QHE (skipping orbits)

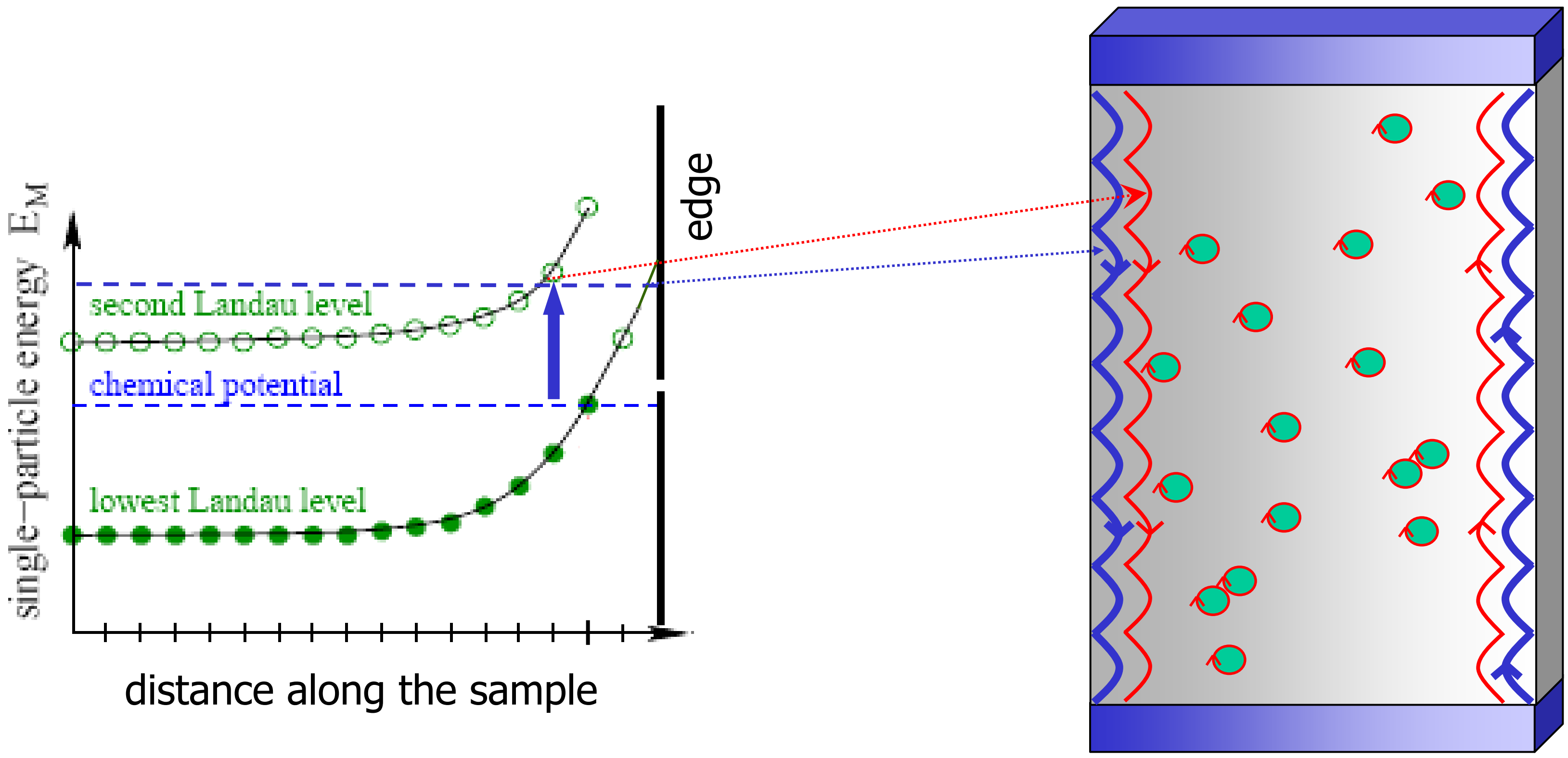
classical : **skipping orbits**

quantum limit : **edge channels**

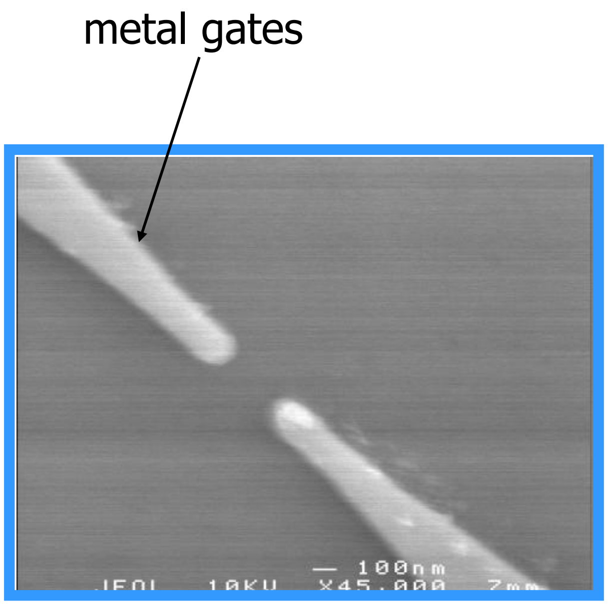
one dimensional objects

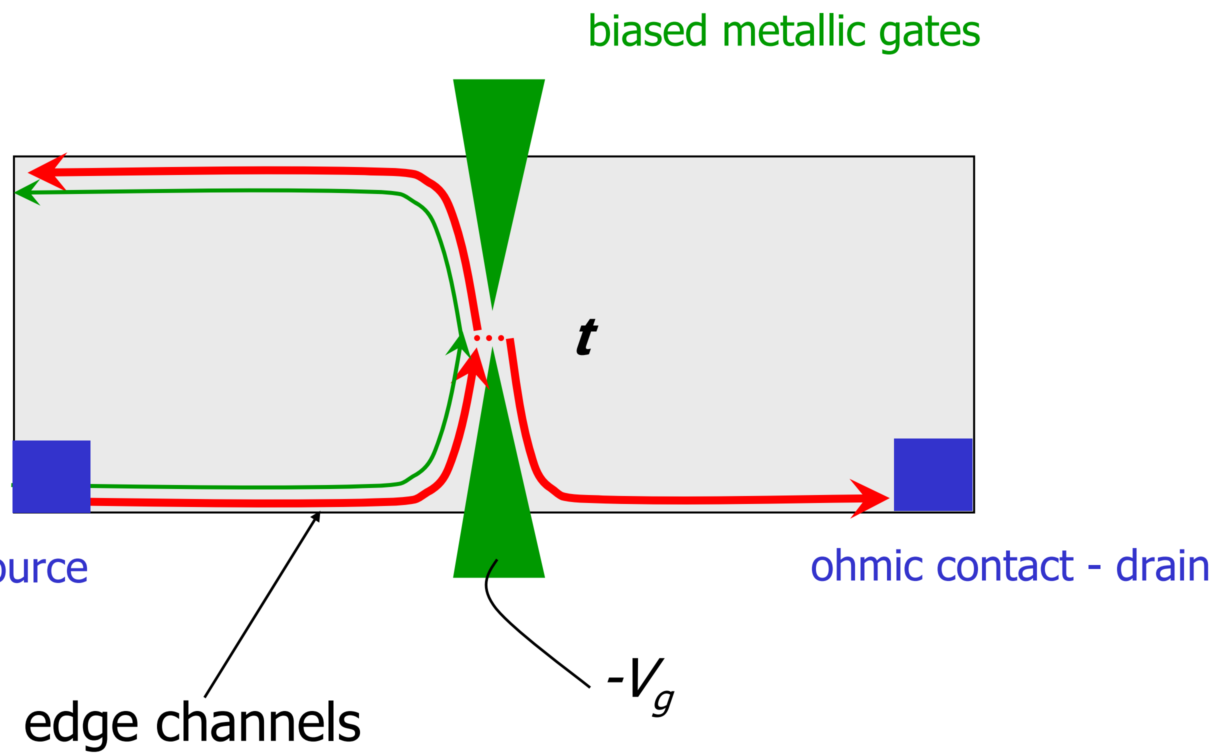


edge channels in QHE

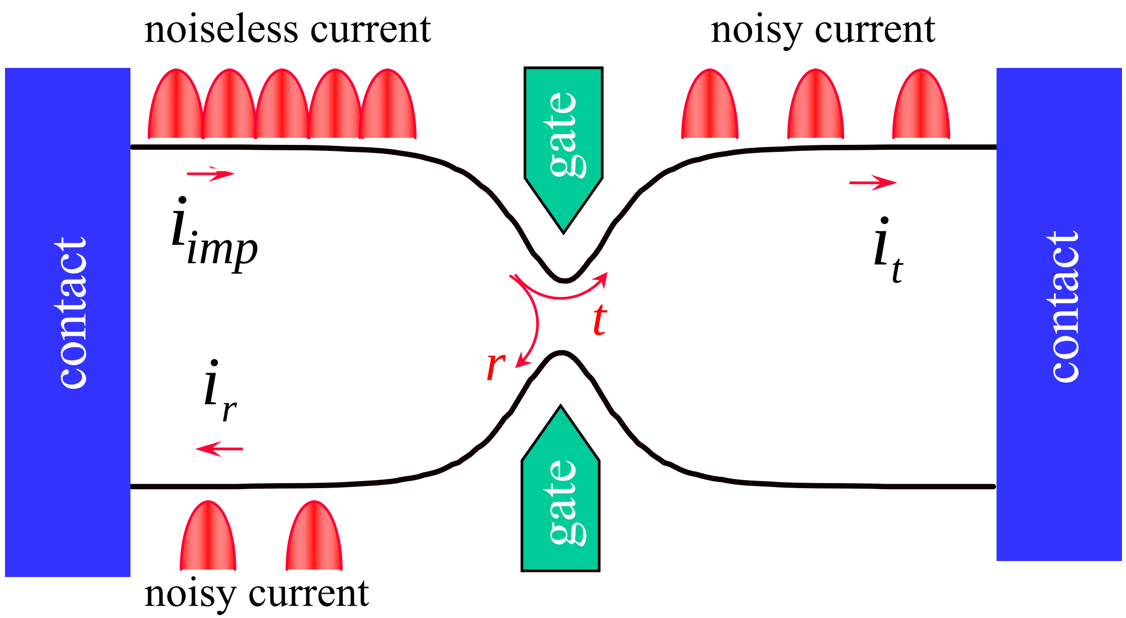


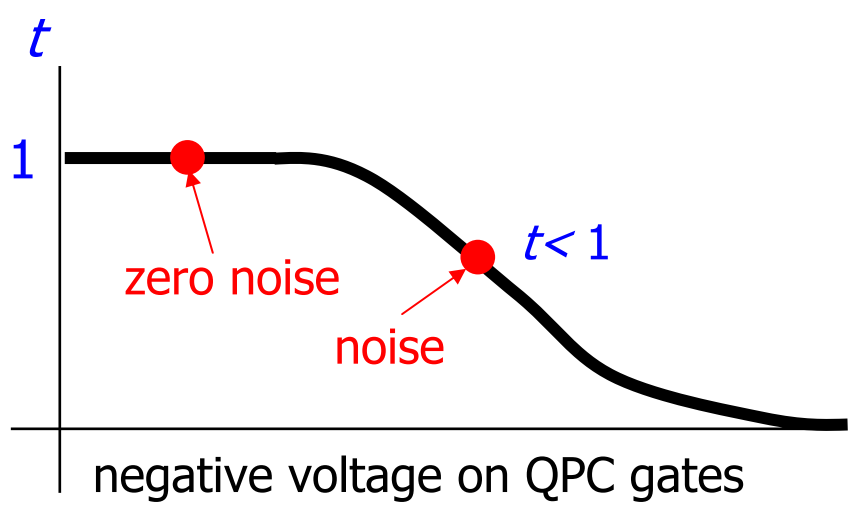
partitioning by quantum point contact (QPC)





partitioning edge states





experimental considerations

$n_s \sim 1\text{x}10^{11}$ cm $^{-2}$; $\mu \sim 10\ \text{x}10^{6}$ cm^2/V-s

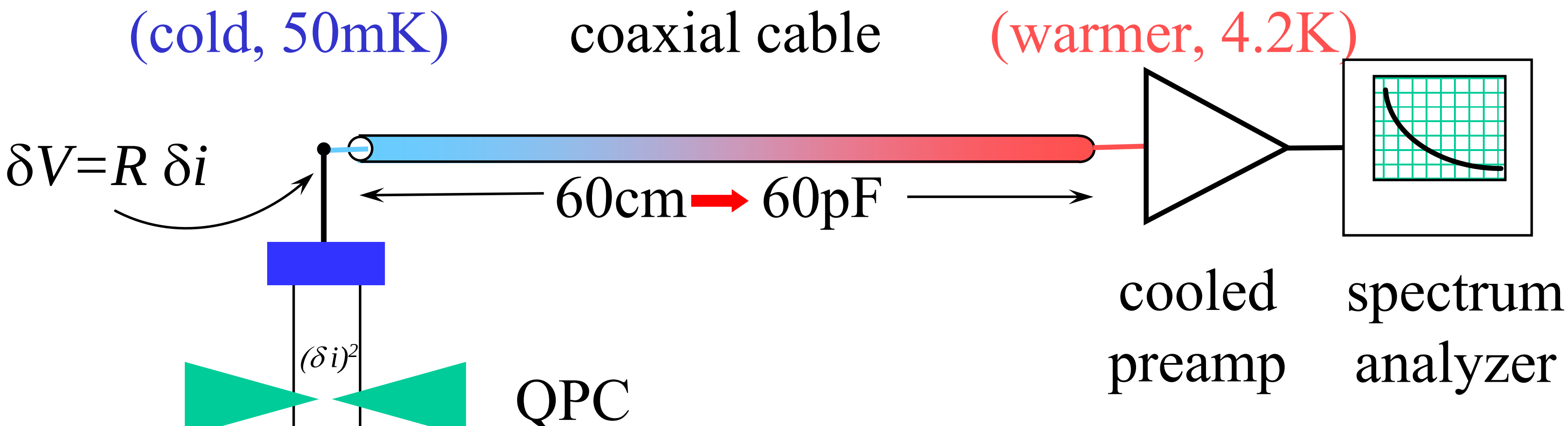
shot noise signal..................... $T^* \sim$ 40mK

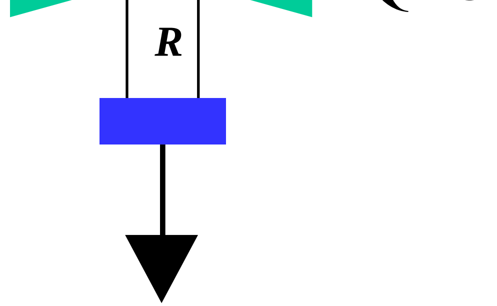
noise of electronics................ $T^* \sim$ 3.5K

home-made cryogenic preamplifier

$T^* \sim$ 100-200mK at $f_0 \sim$ 1MHz (above 1/f noise)

difficulties in measurements





☞ QPC resistance $R \sim 100\text{k}\Omega$

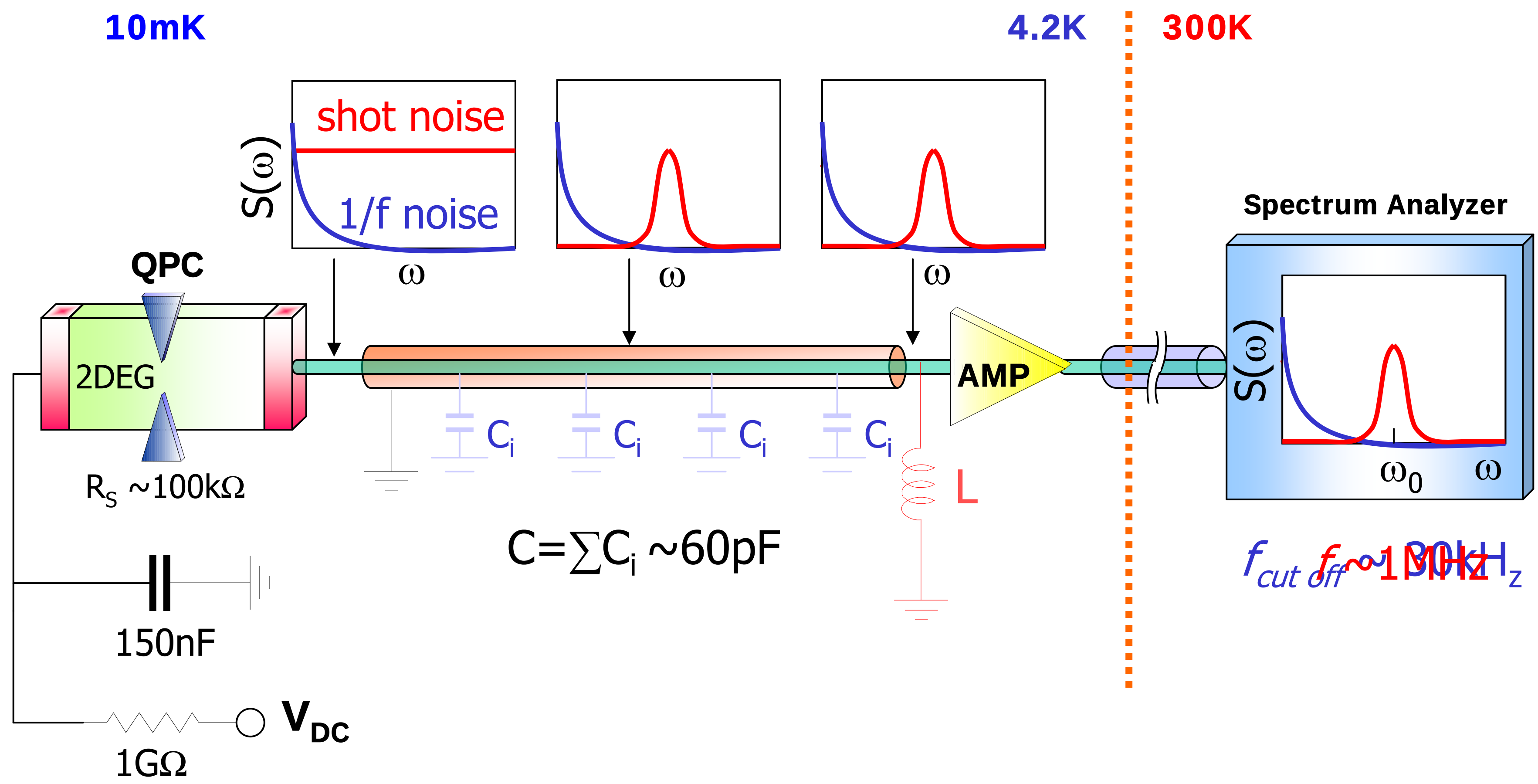
☞ coax capacitance $C \sim 60\text{pF}$

↓

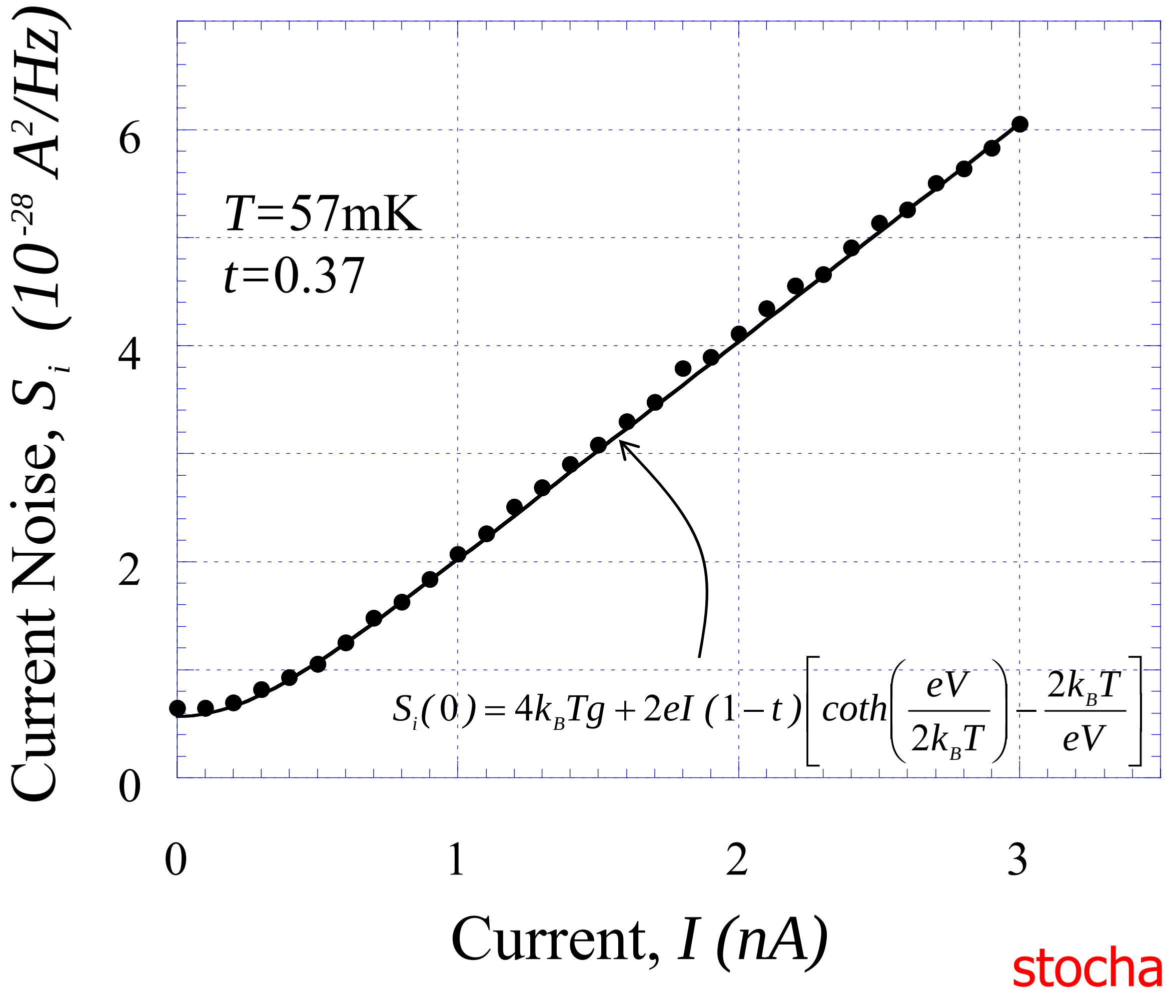
$$f_{max} = 1/(2\pi RC) \sim 30\ \text{kHz}$$

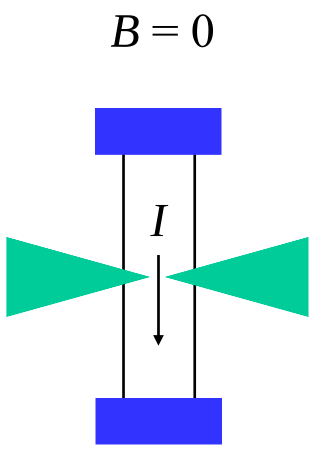
∴ $1/f$ noise is large

experimental setup



shot noise in QPC at $B = 0$





Reznikov *et al.*

stochastic transport

partitioning edge channels of quasiparticles

1d fractional edge channels - experimentalist view

quasiparticles in edge channels → chiral Luttinger liquid (CLL)

X. G. Wen (1991)

fractional charges are interacting

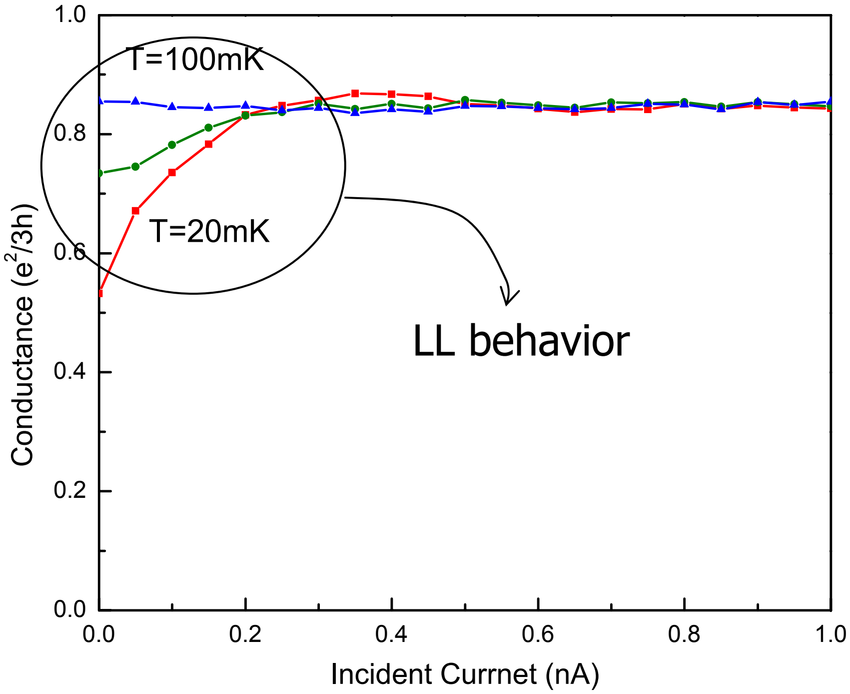
partitioning events may be correlated (not stochastic)

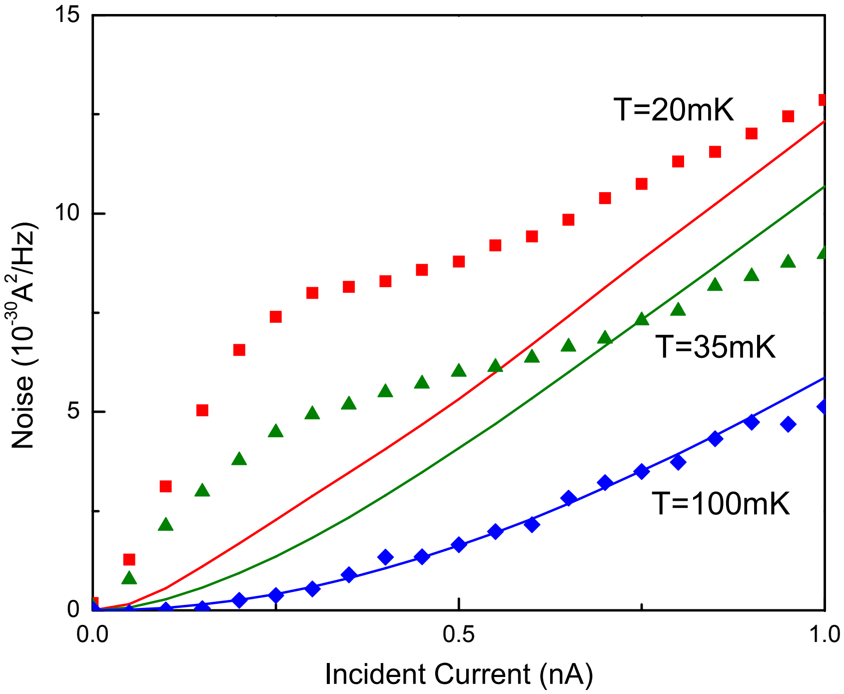
non-linear *I-V*

non-binomial noise

chiral LL: temperature dependence

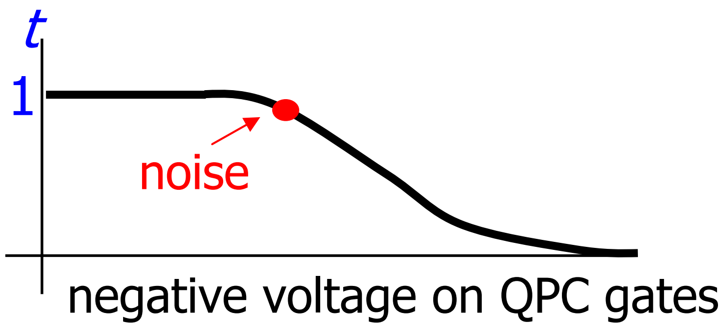
weak backscattering by QPC

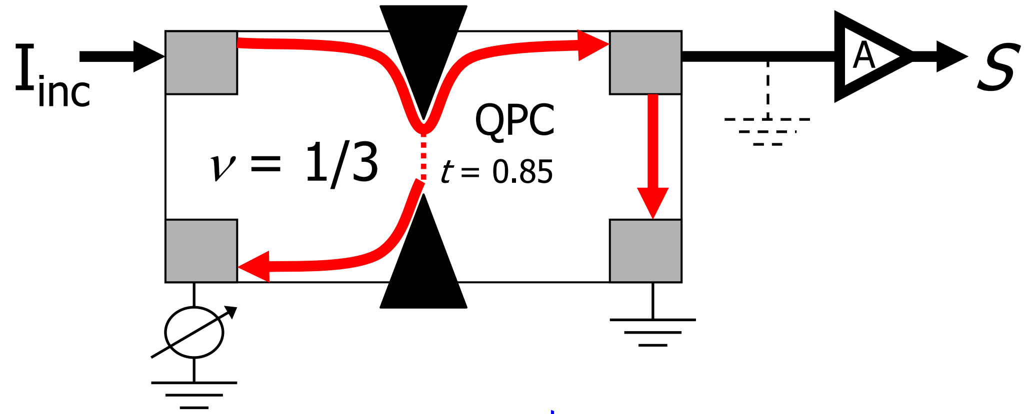


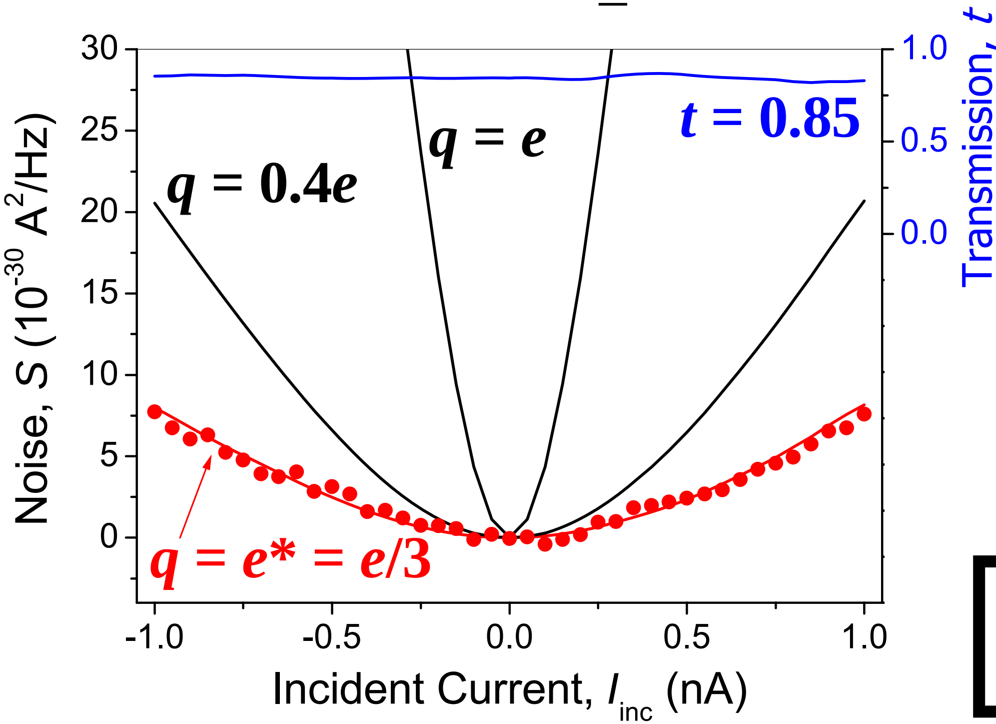


elevated temperature $\rightarrow$ poissonian shot noise

quasiparticles at $\nu = 1/3$, T = 65mK

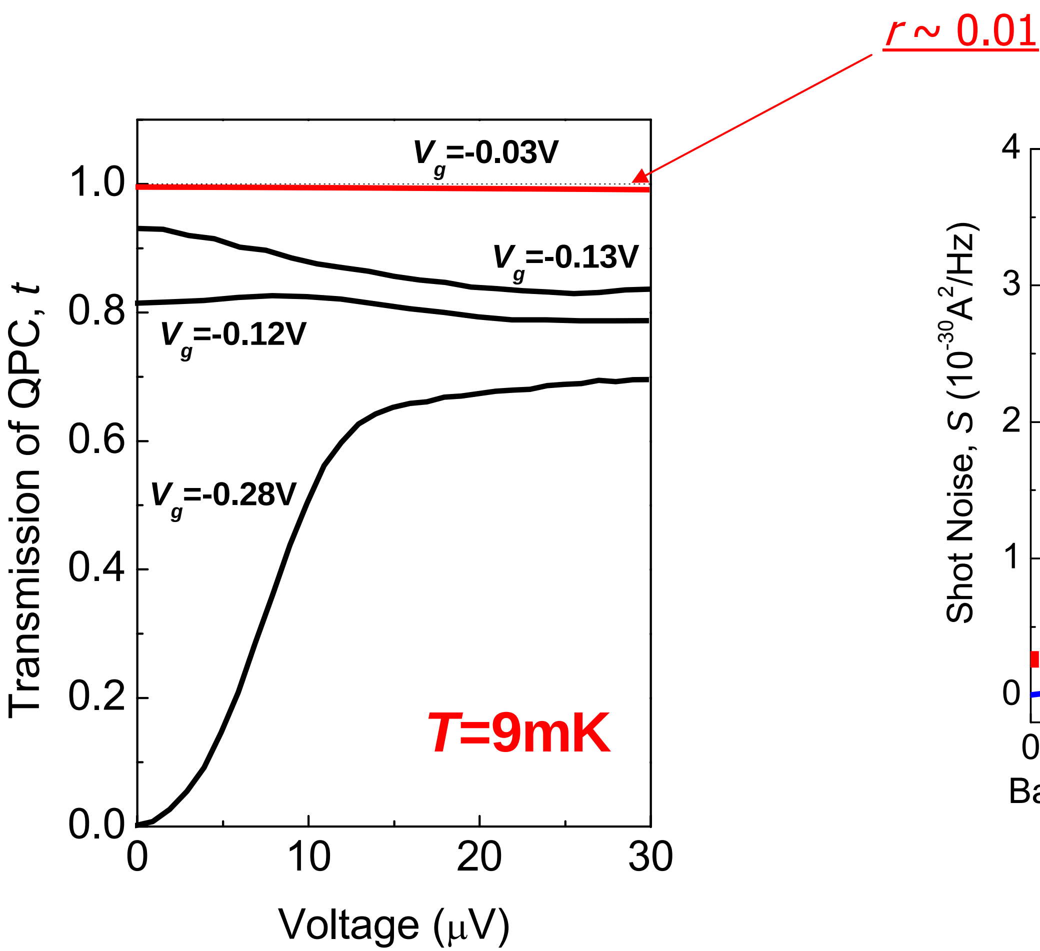


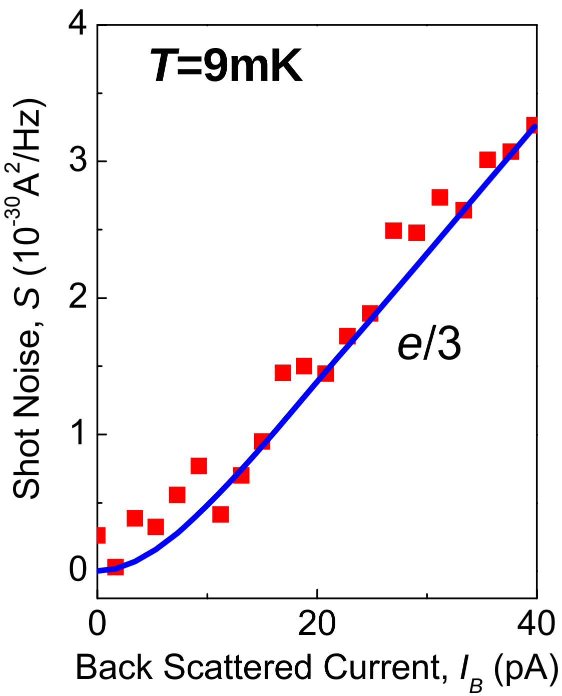




$e^* = e/3$

extremely weak backscattering $\nu = 1/3$, $T < 10$mK



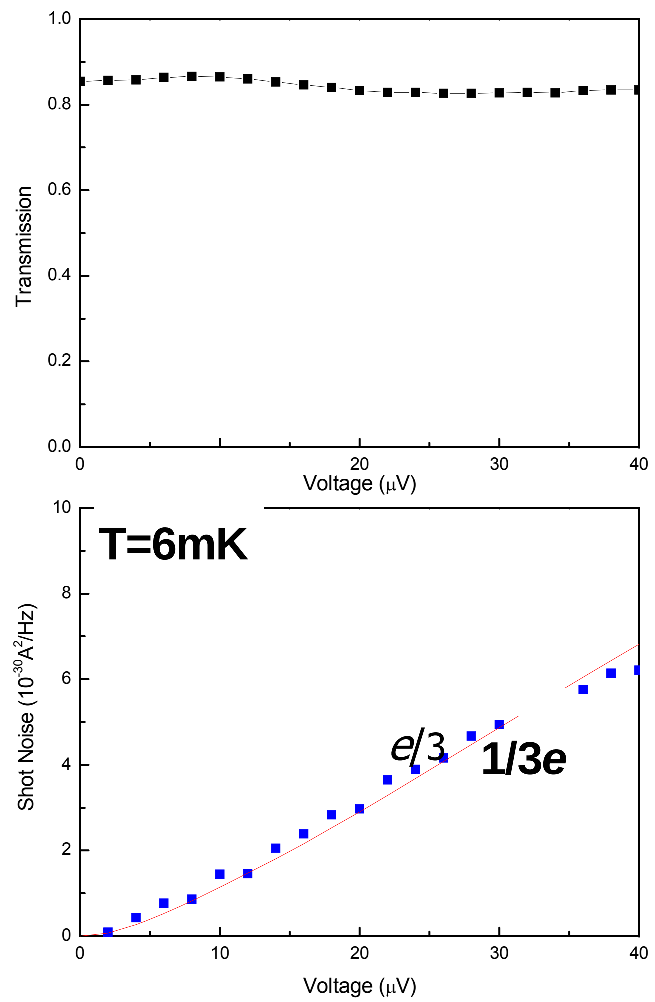


poissonian behavior

charge defined

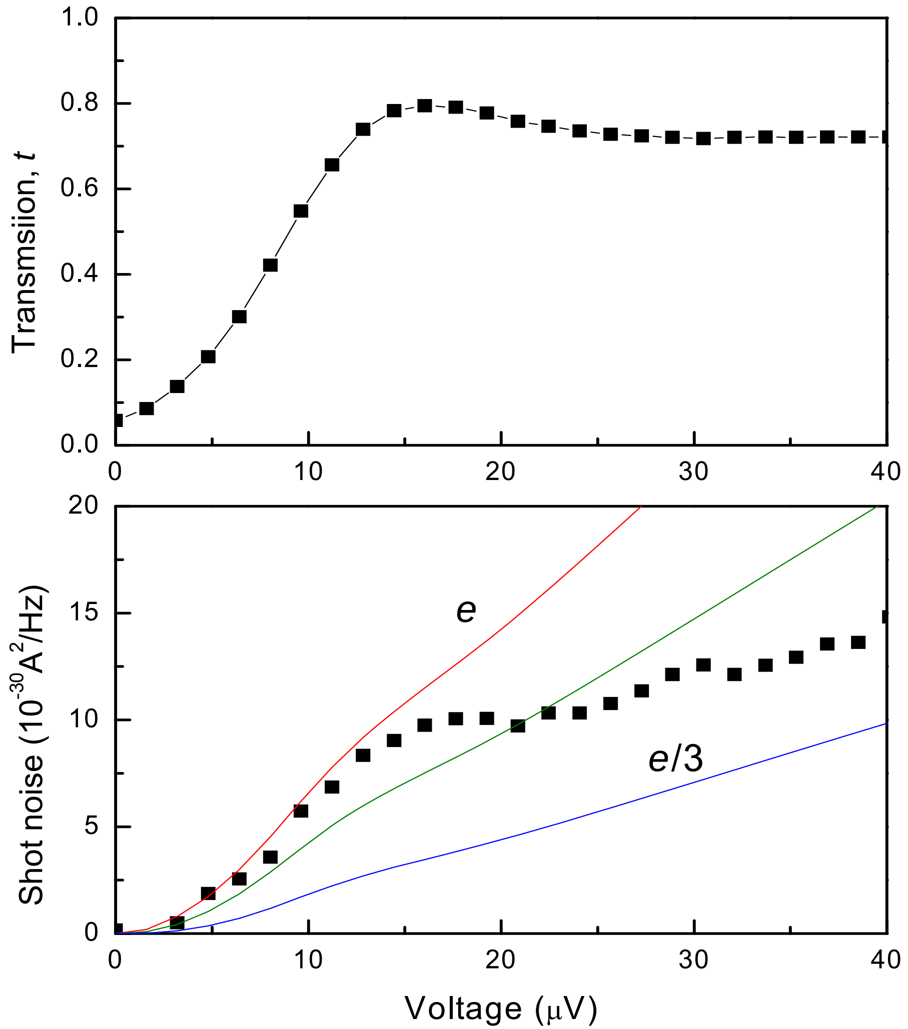
different behvior $\nu = 1/3$, $T < 10\text{mK}$

energy independent



different behvior at $\nu = 1/3$, $T < 10\text{mK}$

CLL behavior



similar dependence in

high and low transmission

how to treat multiple channels transport ?

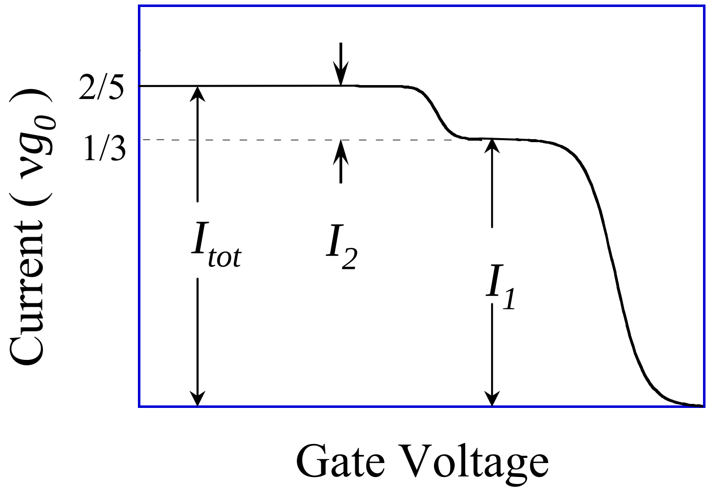
two edge channels - composite fermions approach

☞ $I_{tot} = I_1 + I_2$

☞ $\langle \delta I_{tot}^2 \rangle = 0$

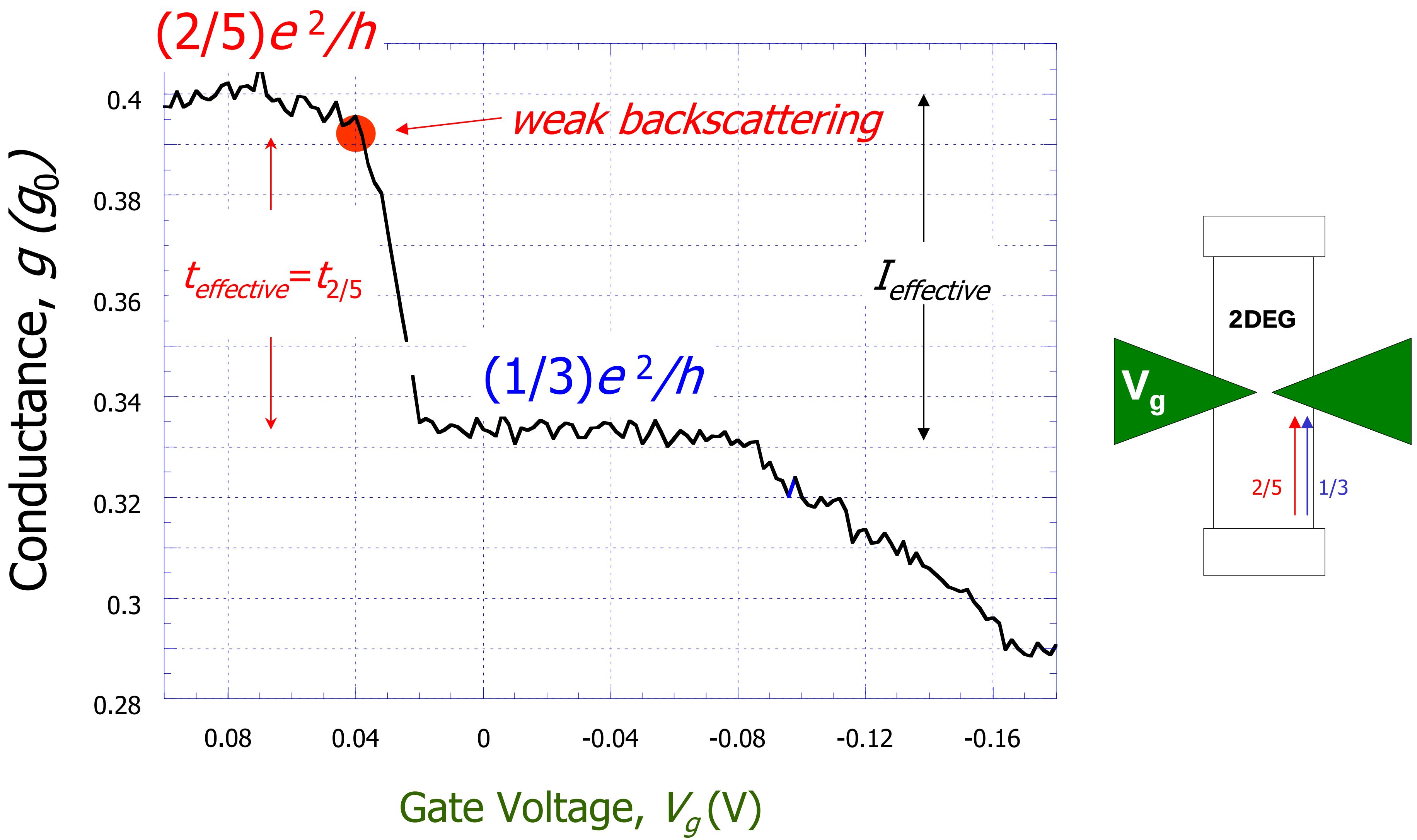
☞ $\langle \delta I_1^2 \rangle = 0$

$$\langle \delta I_2^2 \rangle + 2\langle \delta I_1 \delta I_2 \rangle = 0$$

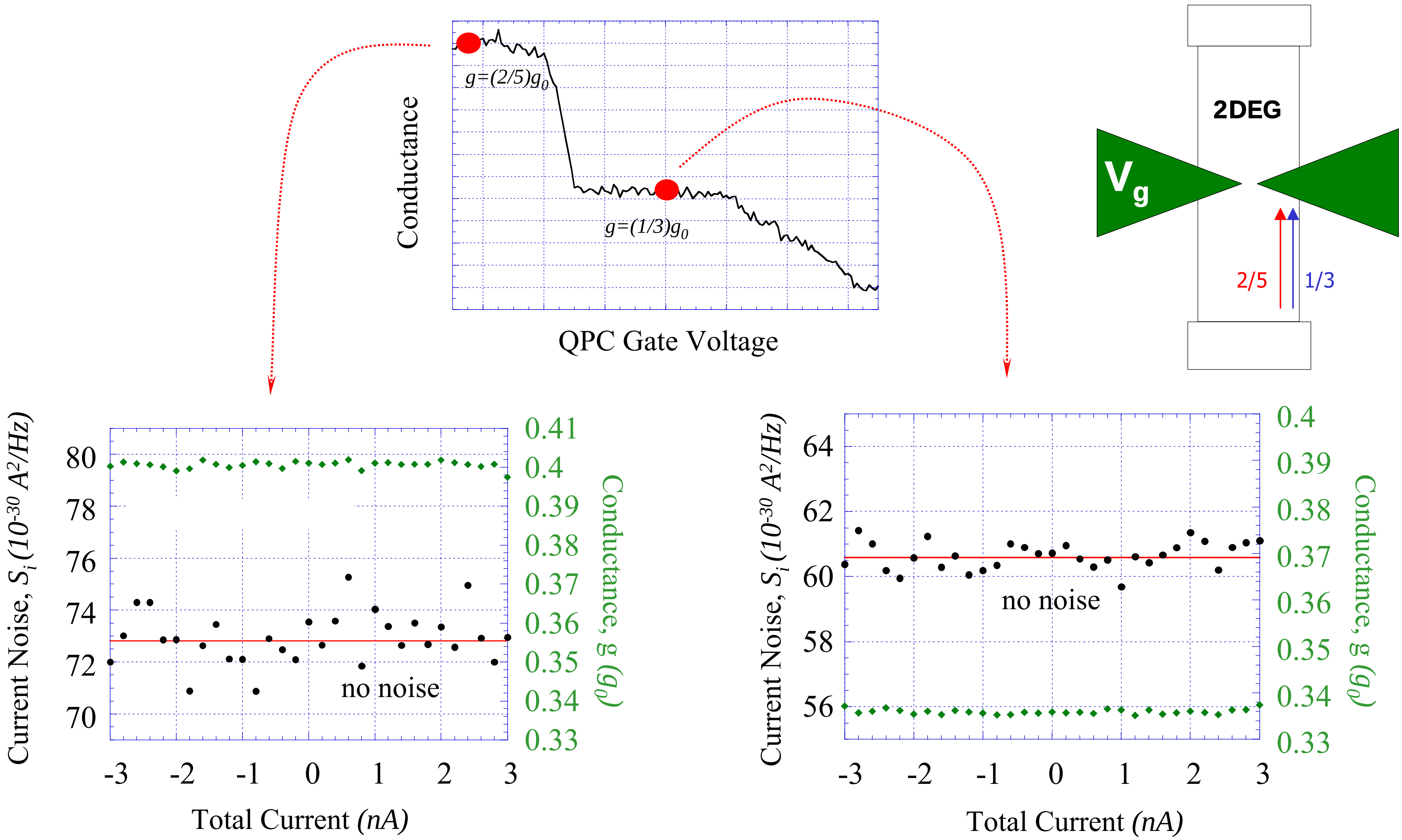


☞ both $\langle \delta I_2^2 \rangle = 0$ and $\langle \delta I_1 \delta I_2 \rangle = 0$ ⇒ *independent channels*

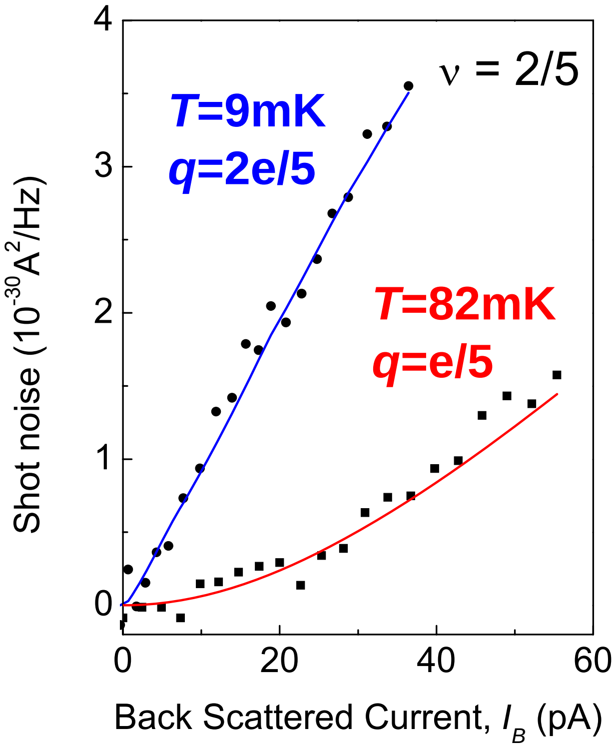
measuring charge at $\nu = 2/5$, $T = 65$mK

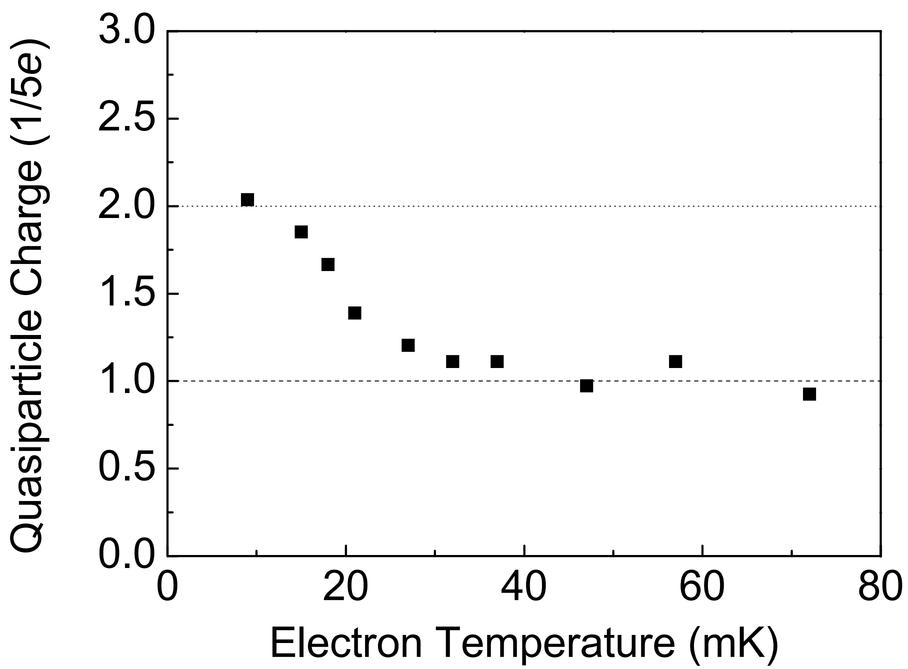


noise on plateaus



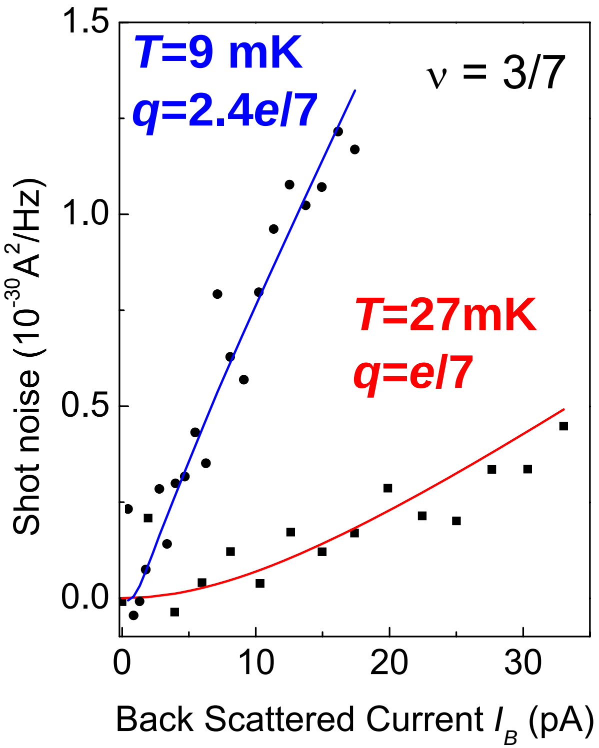
extremely weak backscattering at $\nu = 2/5$





bunching of quasiparticles

very weak backscattering at $\nu = 3/7$



is temperature not low enough?

bunching of quasiparticles

even denominator FQHE

VOLUME 59, NUMBER 15 PHYSICAL REVIEW LETTERS 12 OCTOBER 1987

Observation of an Even-Denominator Quantum Number in the Fractional Quantum Hall Effect

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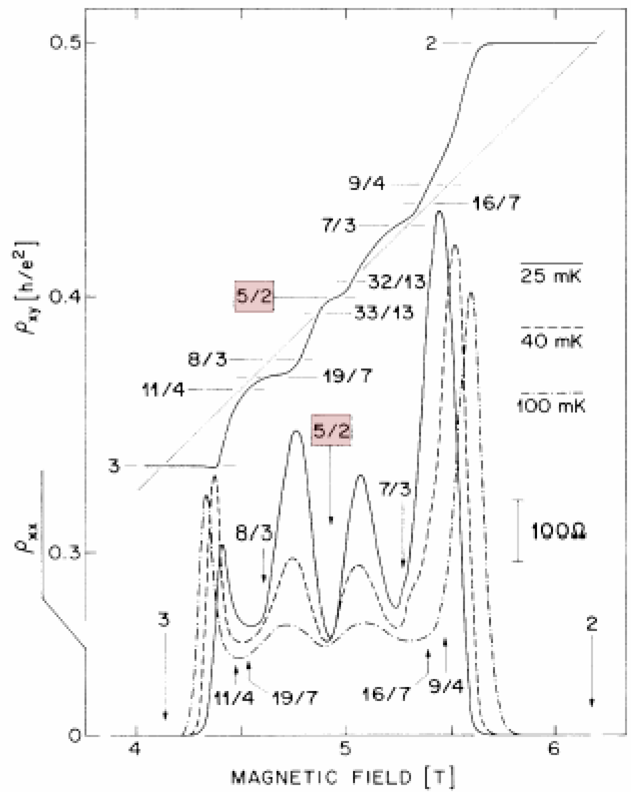
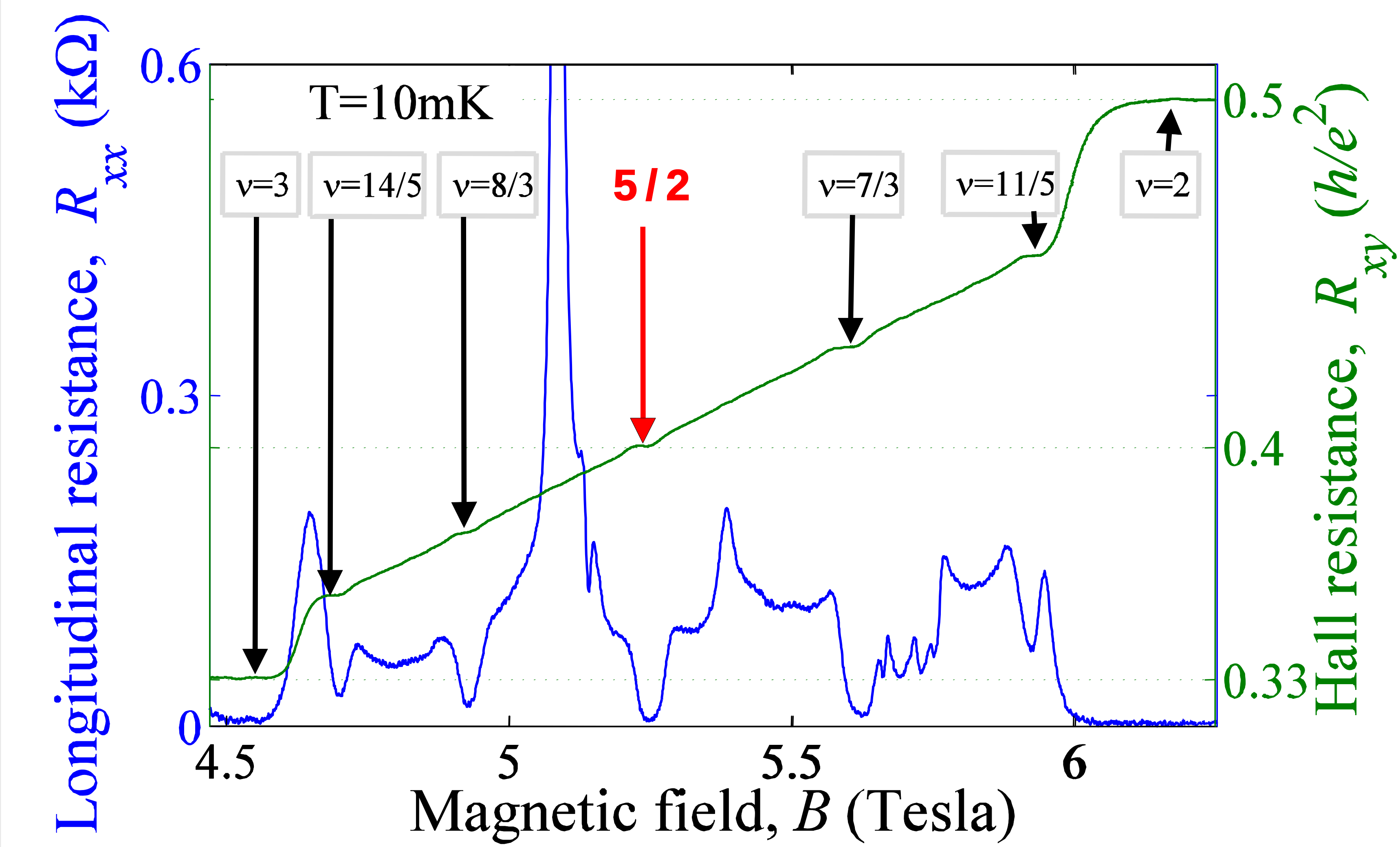


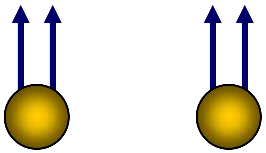
fractional states in the second Landau level

$\mu \sim 30 \times 10^6$ cm²/V-s



Moore - Read theory

$\nu = 5/2 = 2 + 1/2$



$\Delta B = 0$

fermions at $B = 0$

- metal
- superconductor
- exotic phases

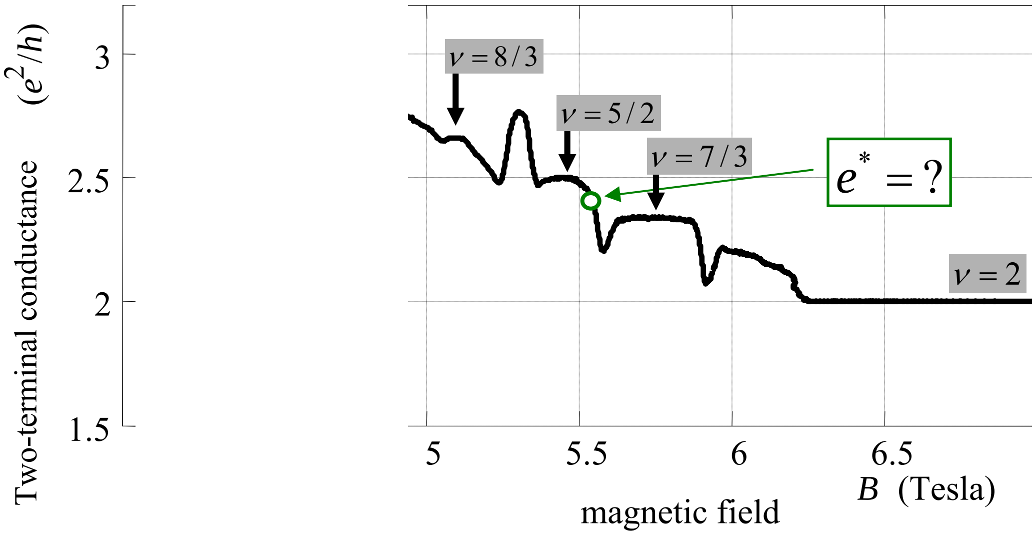
$R_{xx} = 0 \Longrightarrow$ superconductor

non-abelian statistics

$e^* = e/4$

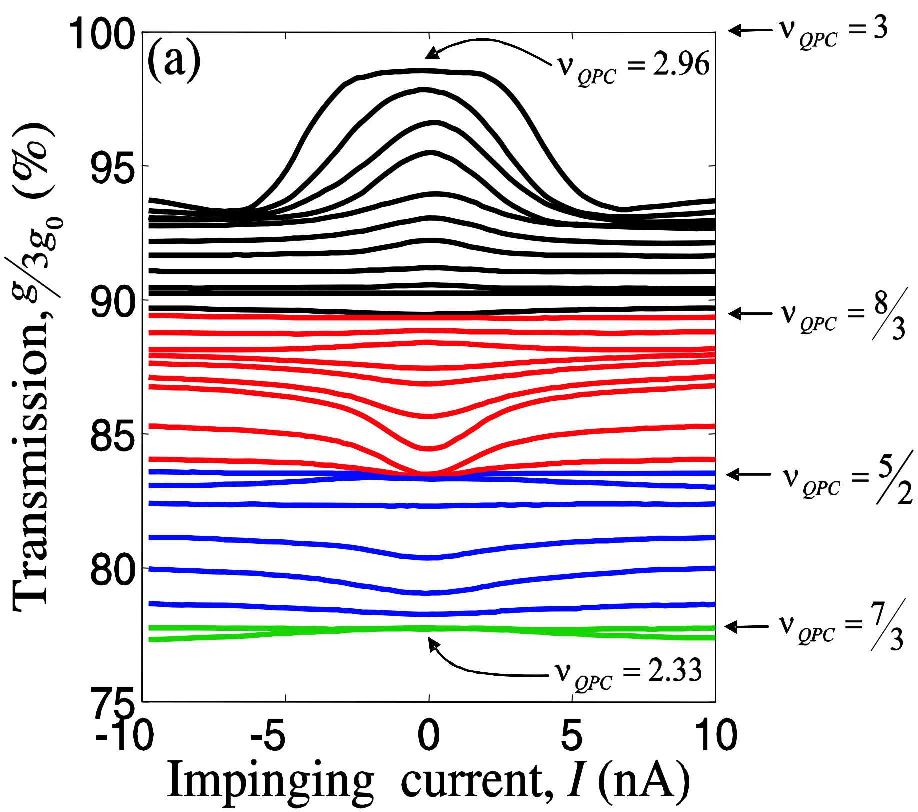
charge in 5 / 2 ?

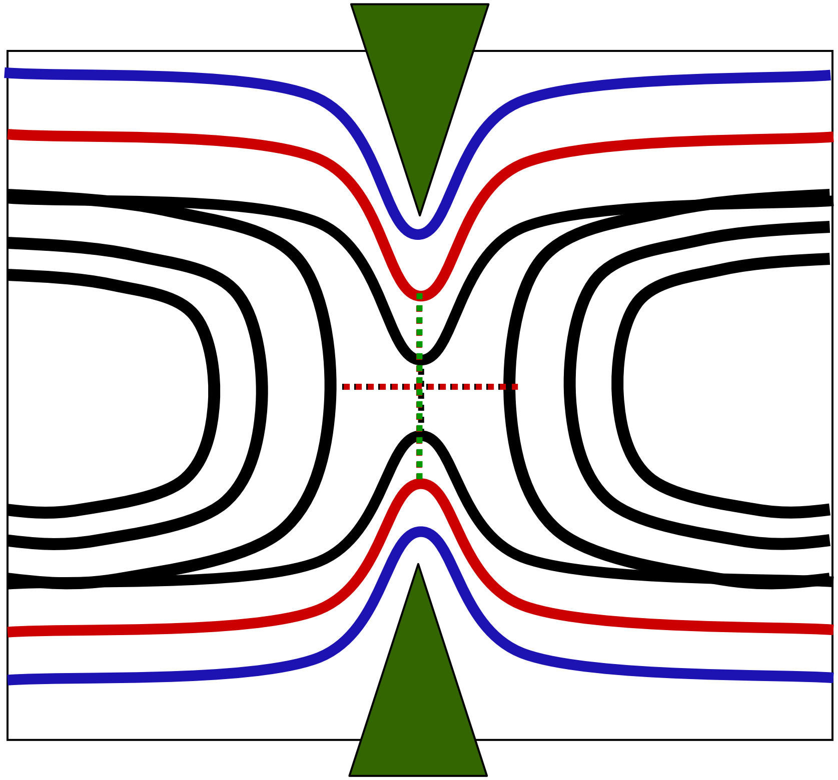
$T = 10\text{mK}$



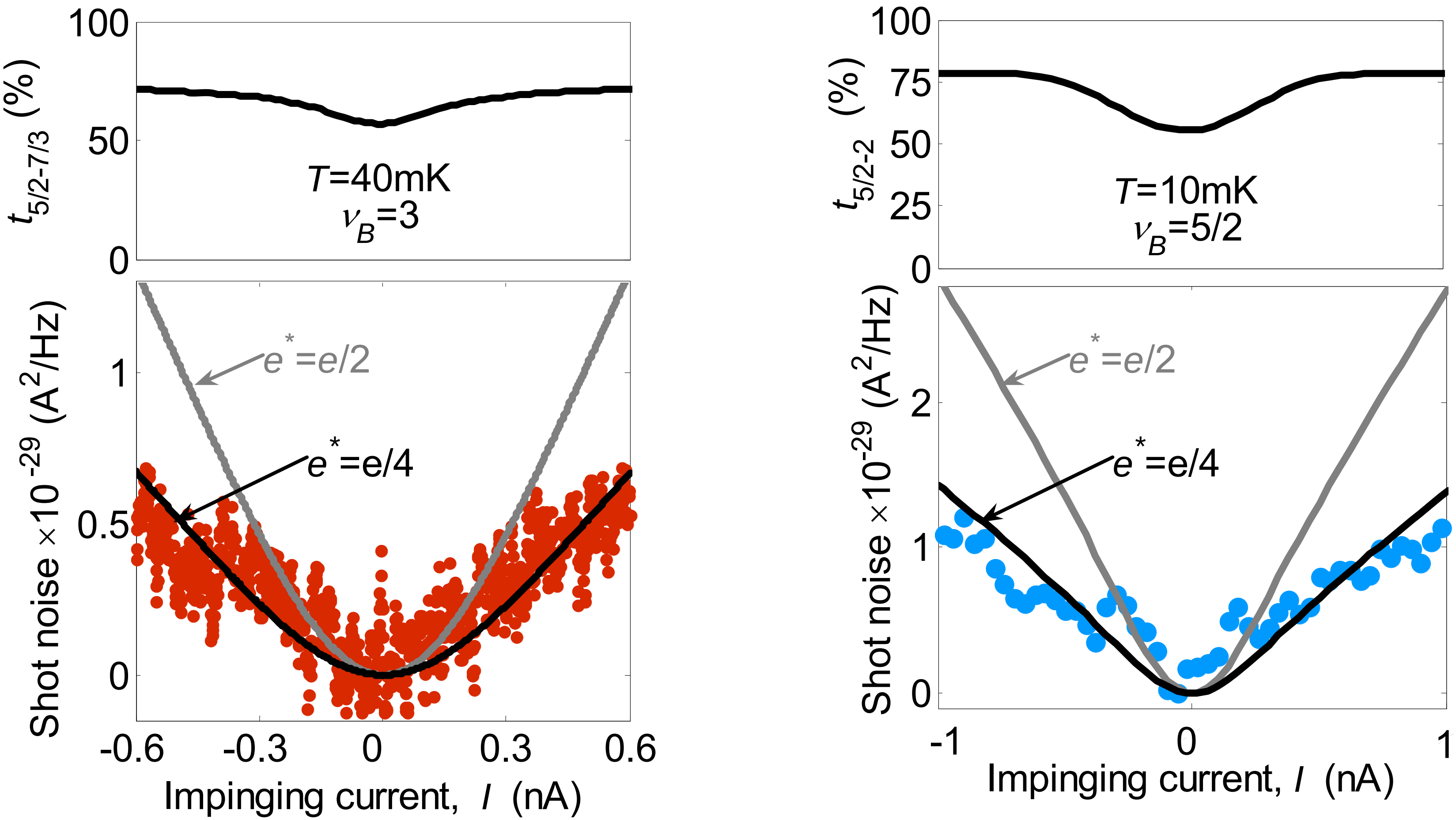
lower lying channels must be identified for $t_{effective}$, $I_{effective}$

identification of edge channels - fractions in higher LL's



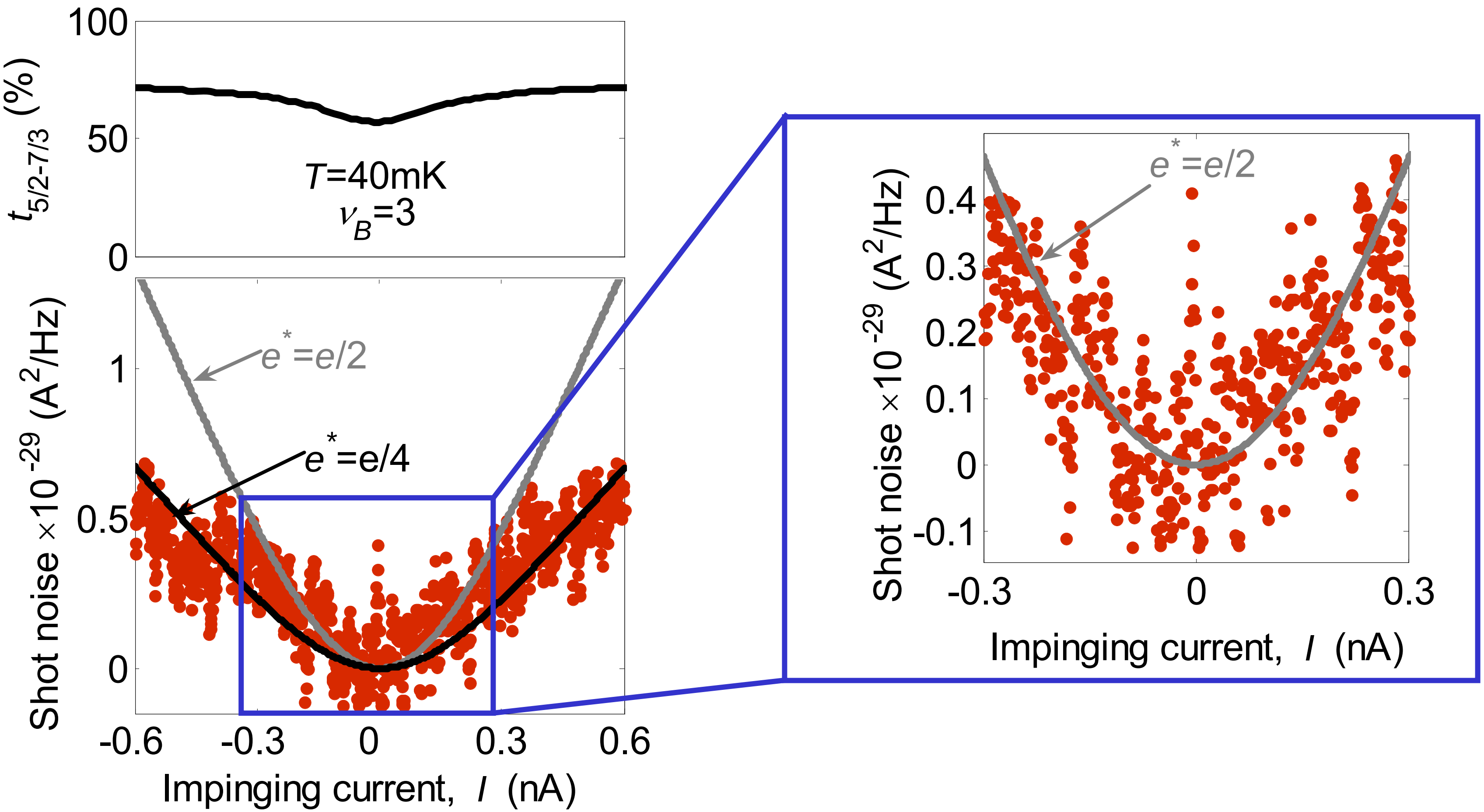


previously published data , $\nu = 5/2$

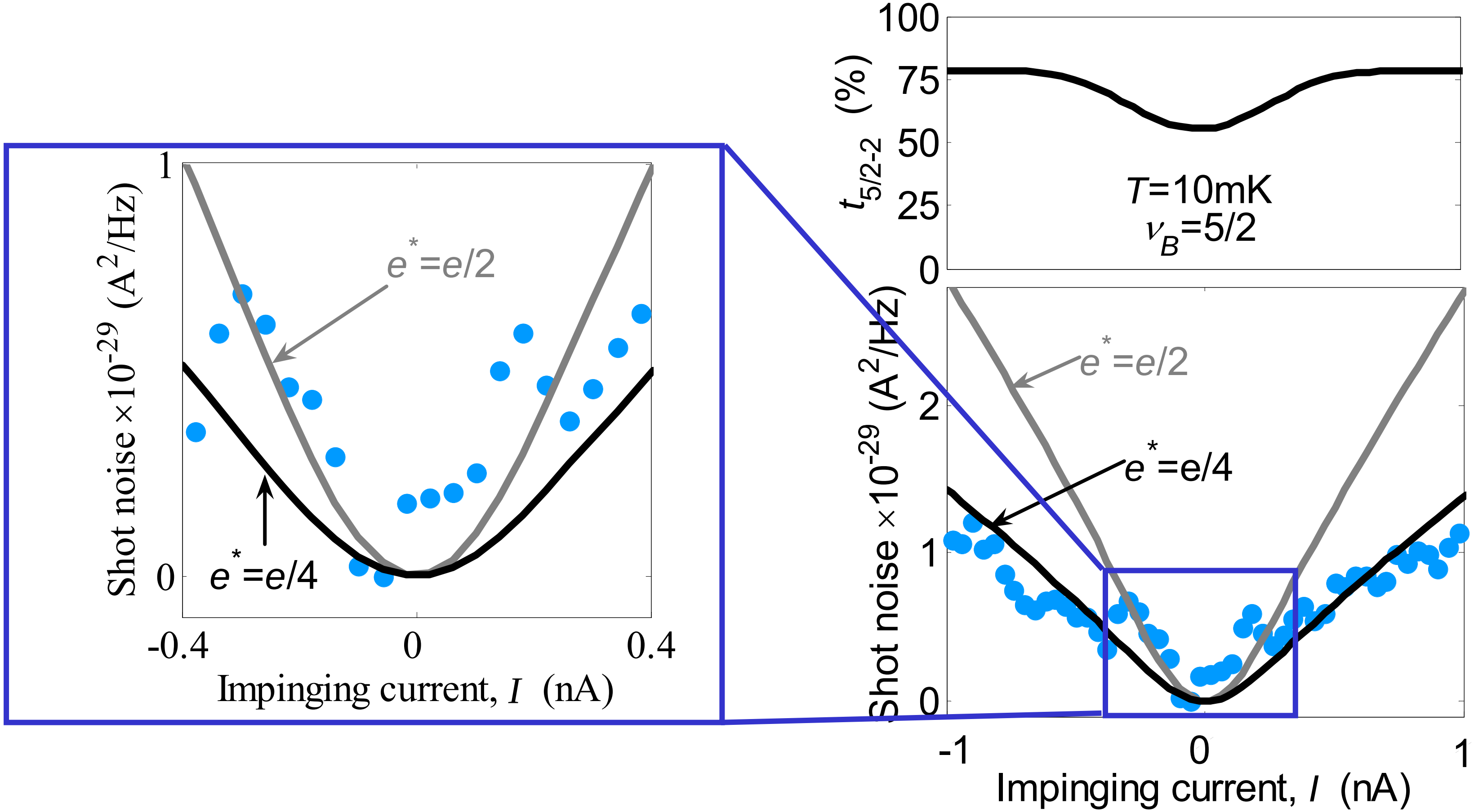


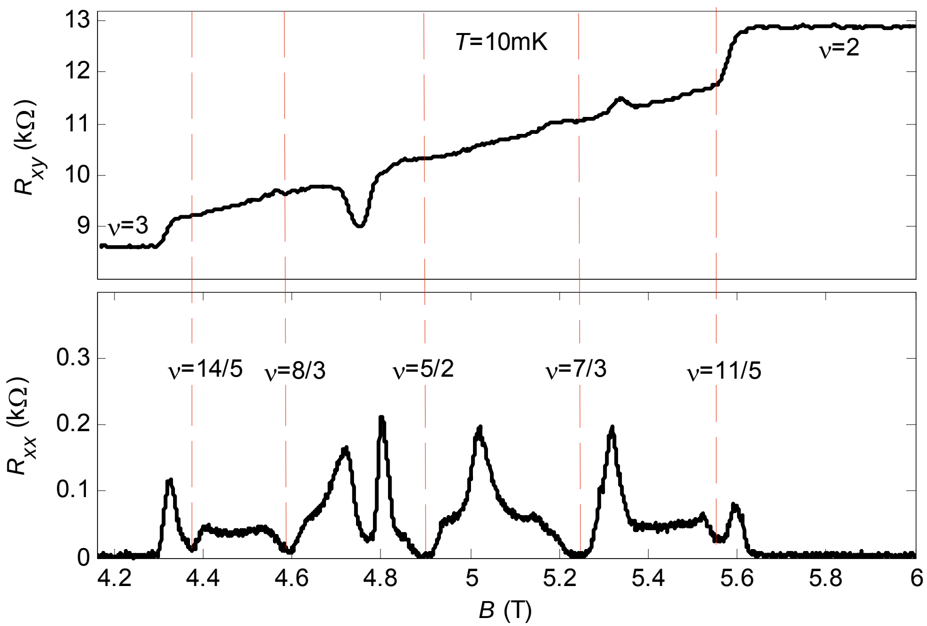
I_{total}(max)=9nA Dolev, Nature (2008) I_{total}(max)=9nA

small current range , $\nu = 5/2$

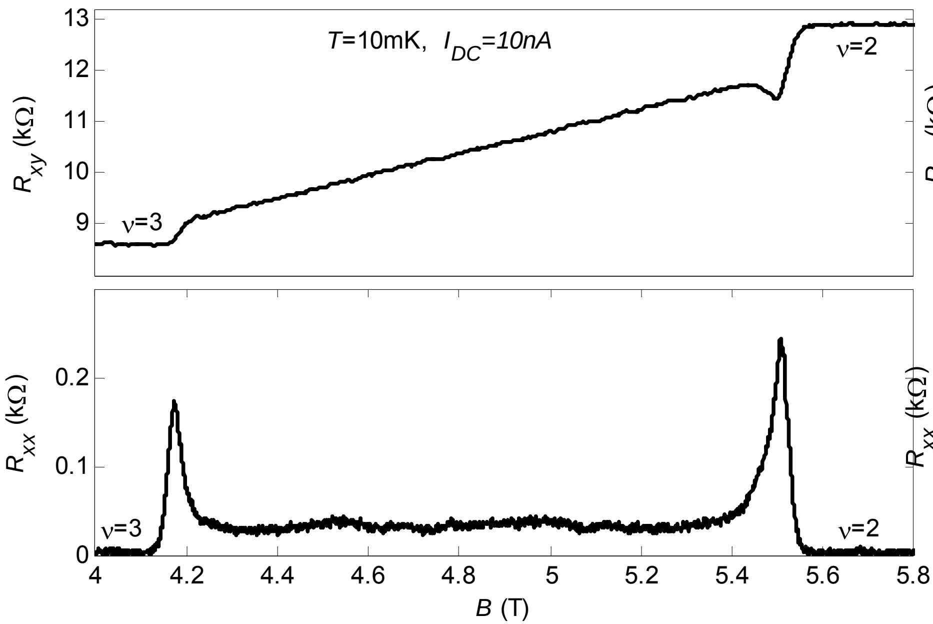


small current range , $\nu = 5/2$

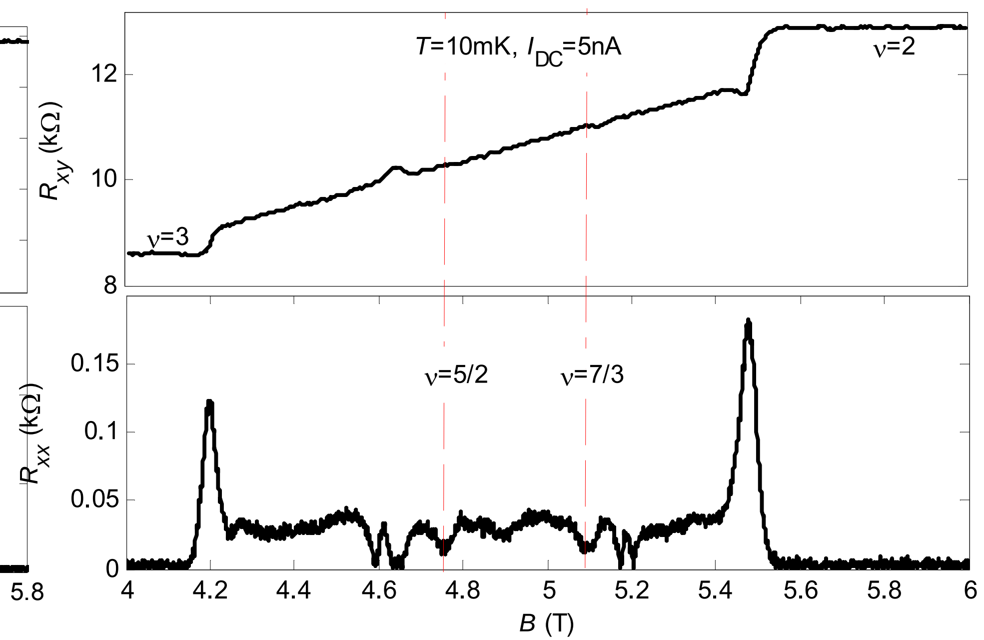




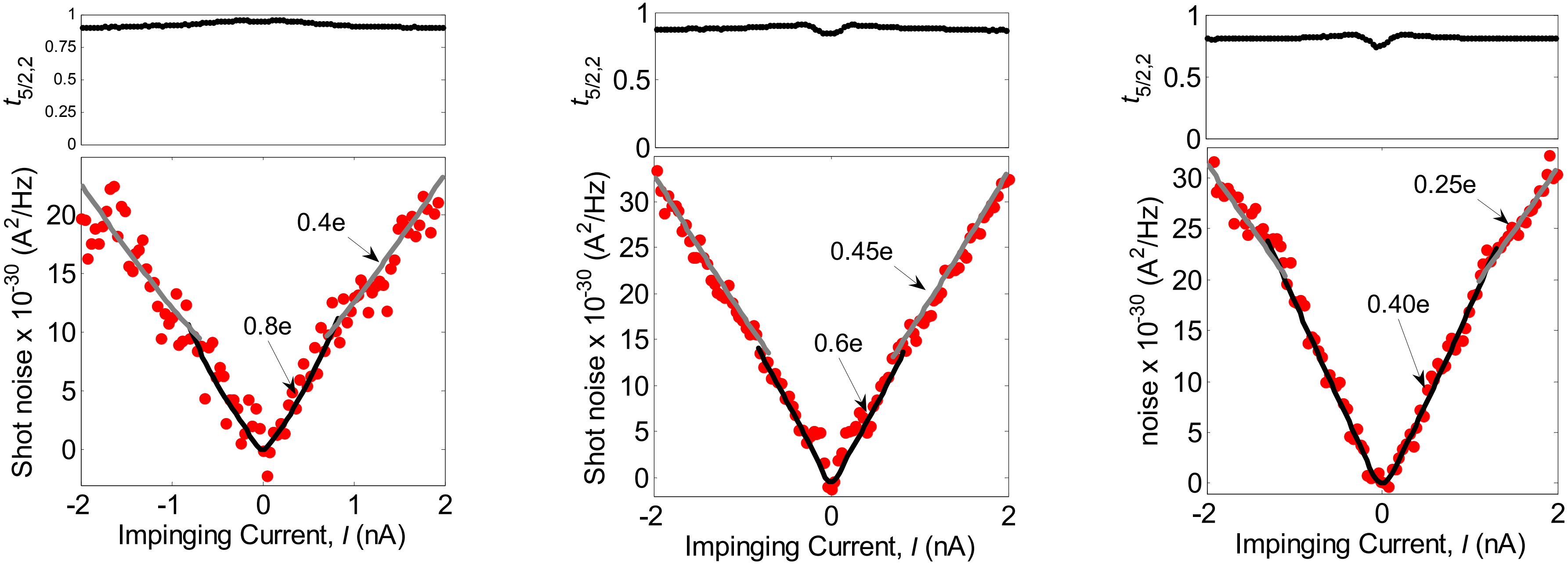
T=10mK
ν=3
ν=2
ν=14/5
ν=8/3
ν=5/2
ν=7/3
ν=11/5
R_{xy} (kΩ)
R_{xx} (kΩ)
B (T)

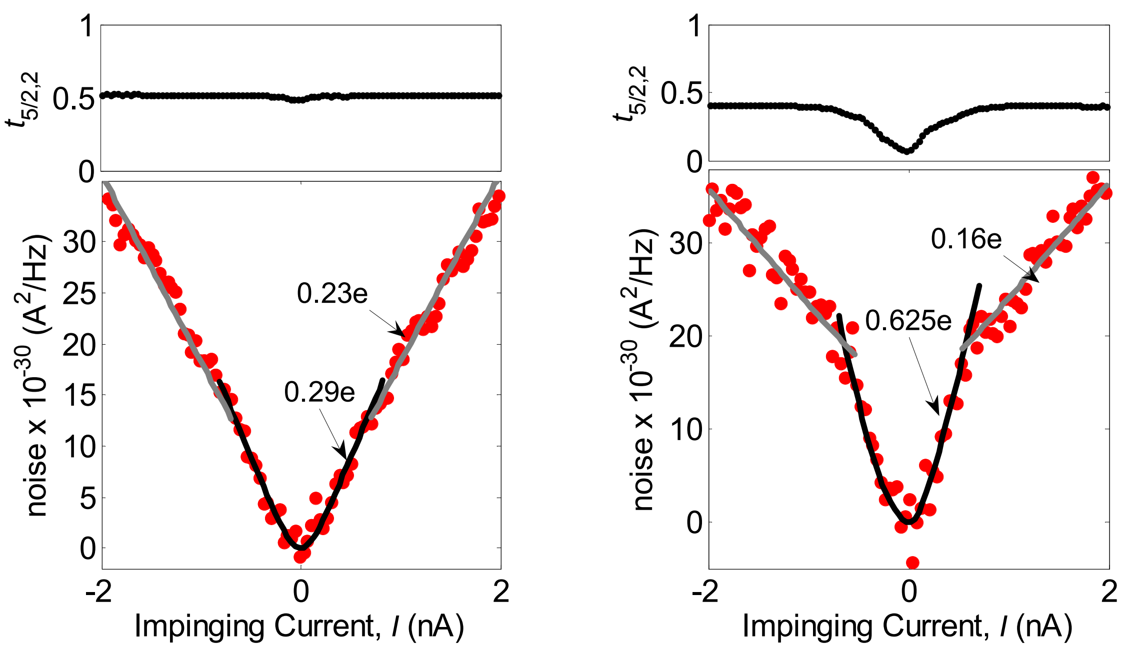


T=10mK, I_{DC}=10nA
ν=3
ν=2
R_{xy} (kΩ)
R_{xx} (kΩ)
B (T)



T=10mK, I_{DC}=5nA
ν=3
ν=2
ν=5/2
ν=7/3
R_{xy} (kΩ)
R_{xx} (kΩ)
B (T)



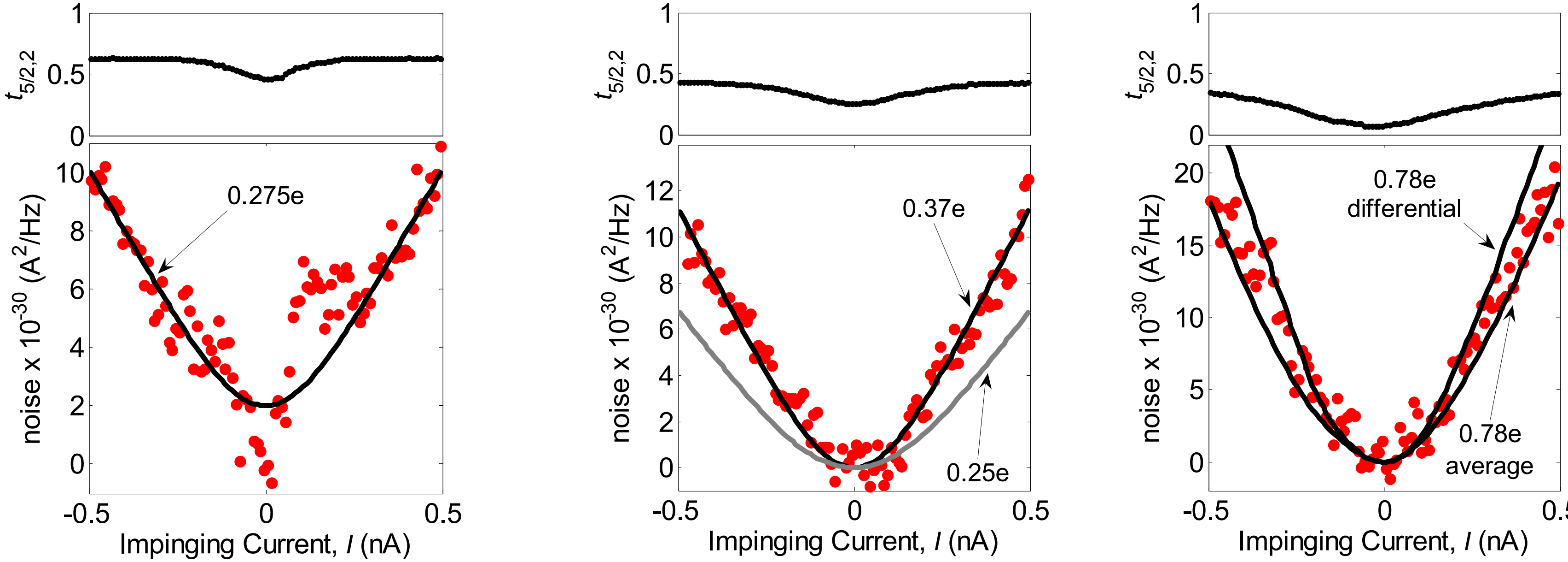


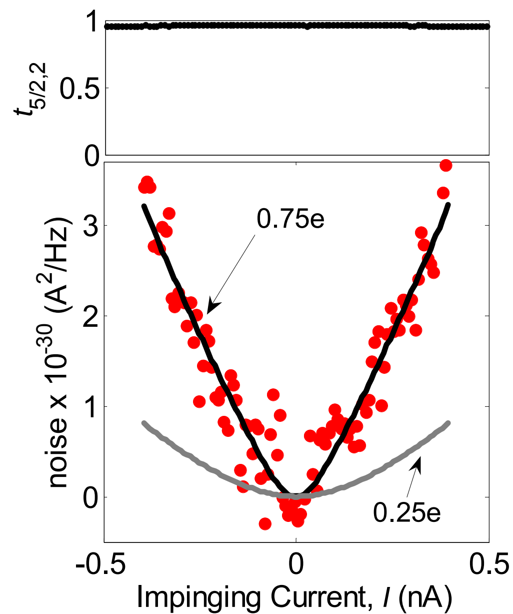
new measurements

ν=5/2, 10mK

cool-down #1

higher resolution in the small current range



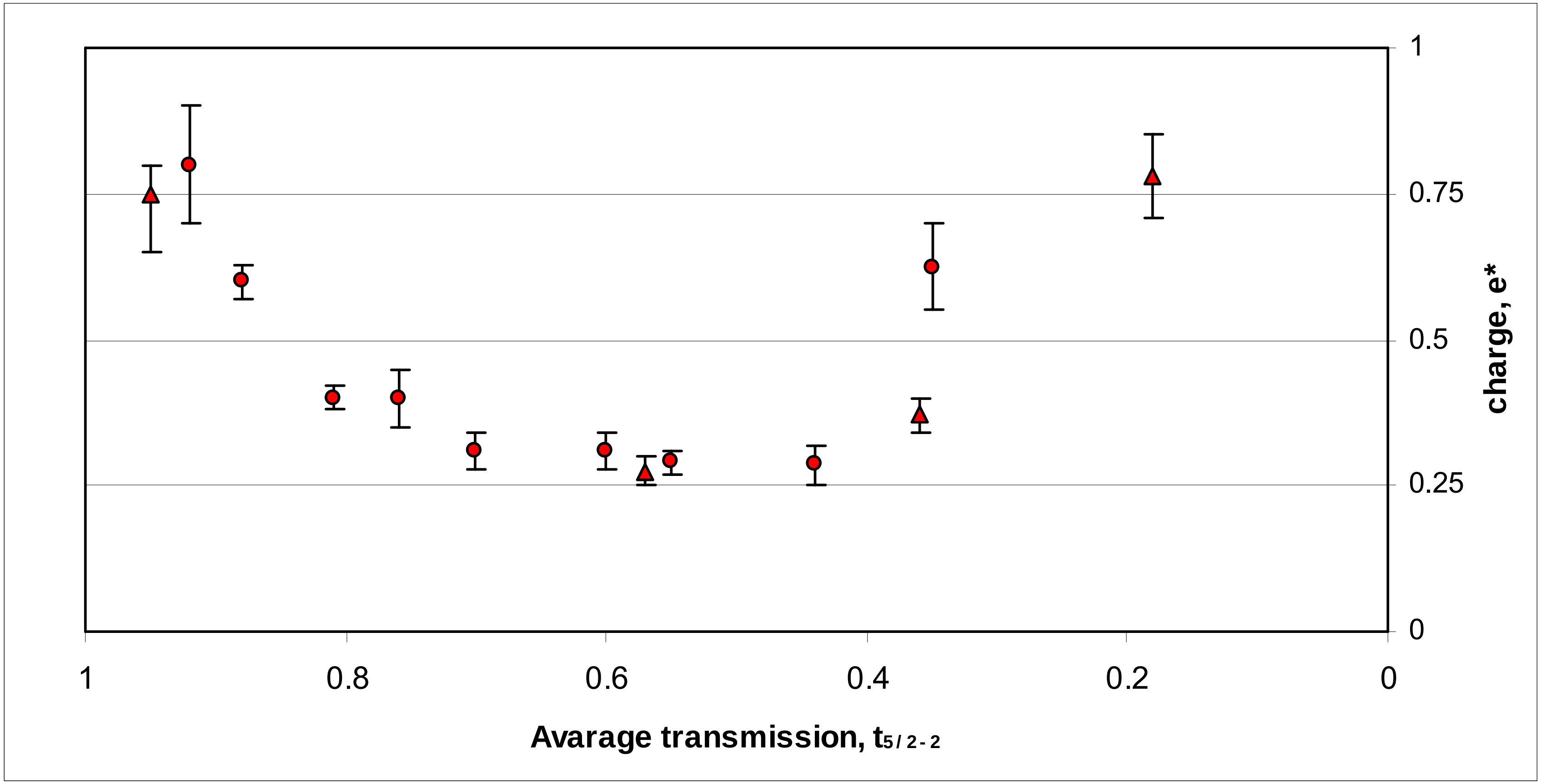


extremely open QPC

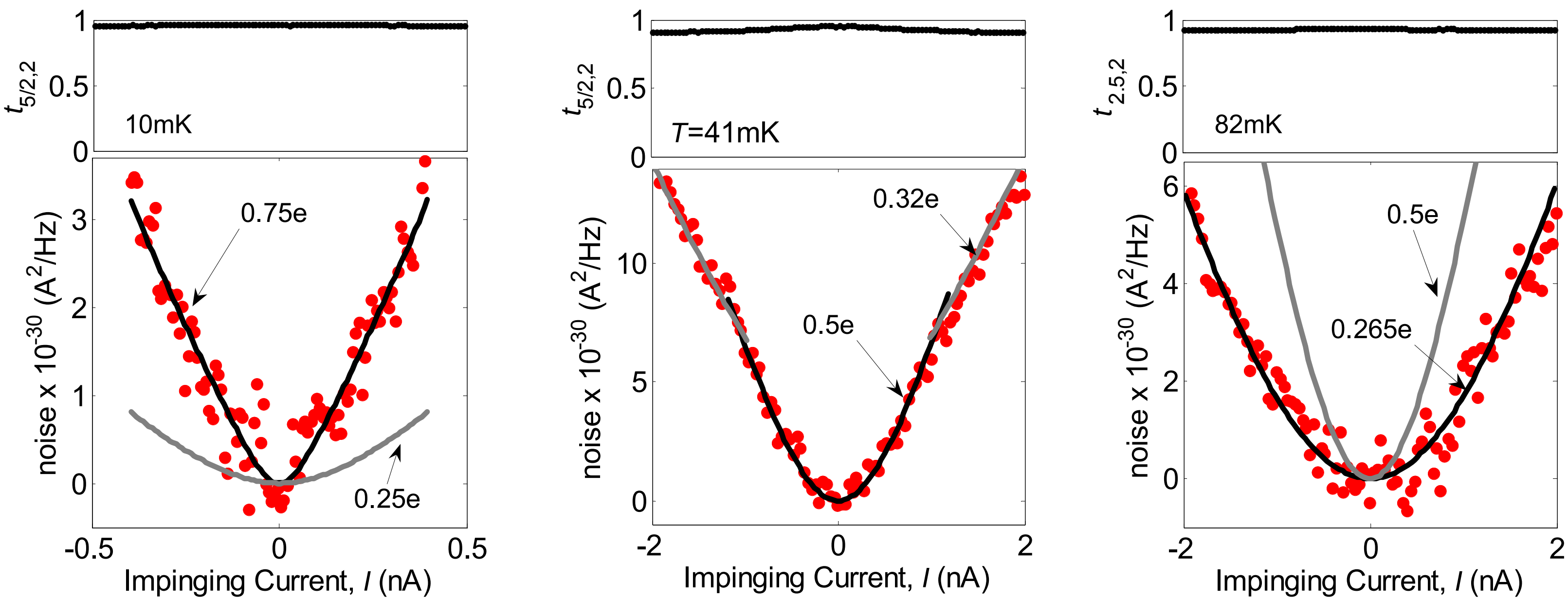
ν=5/2, 10mK

cool-down #2

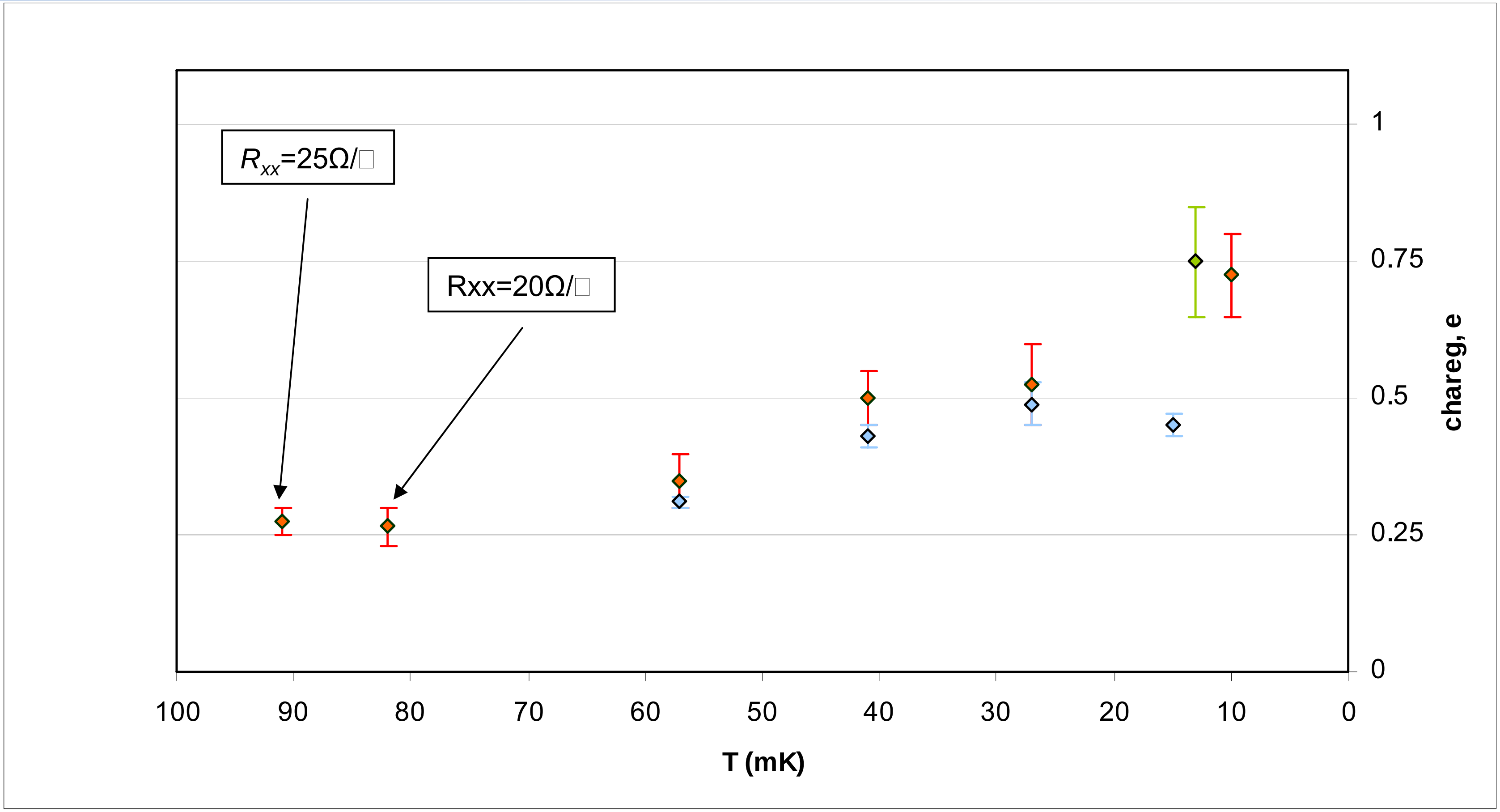
charge *vs* transmission , $\nu = 5/2$



charge *vs* temperature , $\nu = 5/2$



charge *vs* temperature , $\nu = 5/2$



Red - 1st sample: $t_{5/2\text{-}2}$ ~0.95

Blue - 2nd sample, 1st cool-down. $t_{5/2\text{-}2}$ ~0.65

Green - 2nd sample, 2nd cool-down. $t_{5/2\text{-}2}$ ~0.92

(E_{gap}~300-500mK)

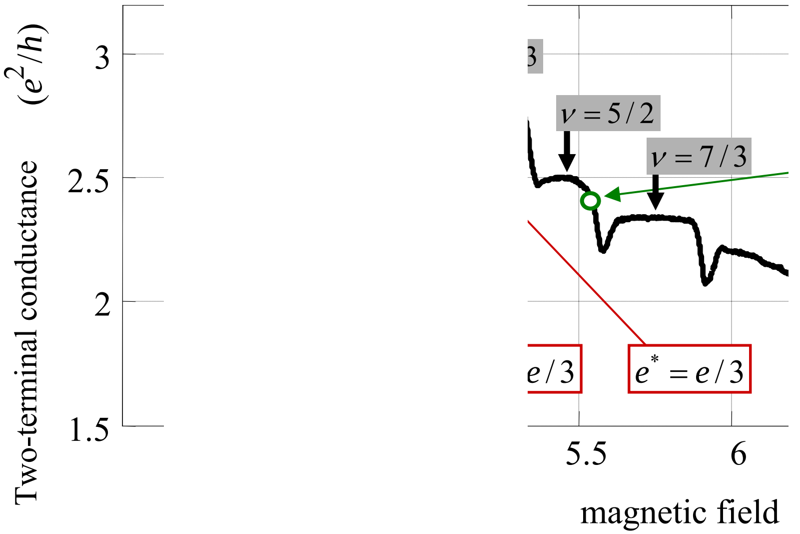
what is the actual scattered charge in the 5/2 channel ?

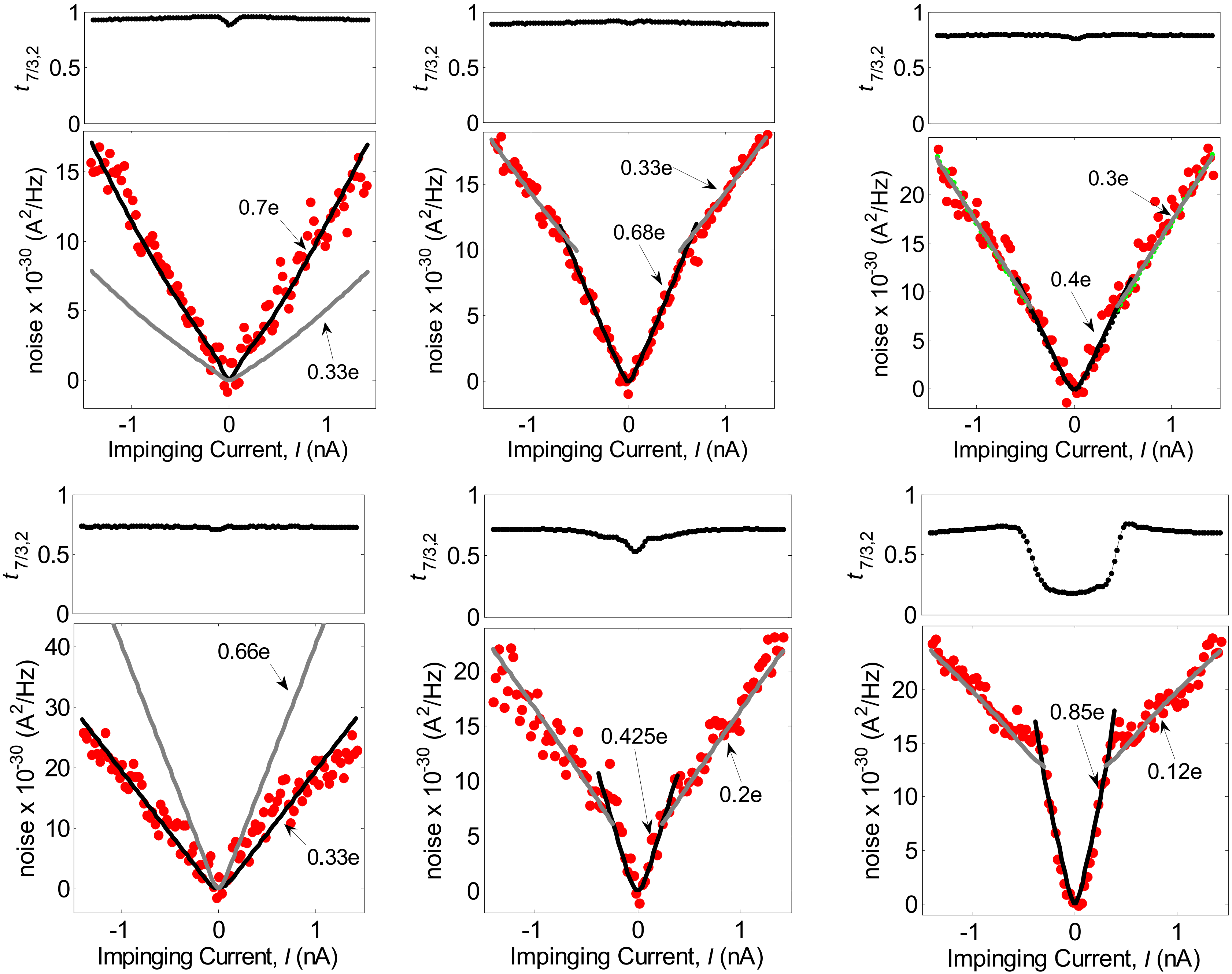
- it seems to depend on the backscattering probability
- it seems to depend on the energy
- it seems to depend on the temperature

will it happen in a ‘nearby fraction’ 7/3 ?

charge in 7 / 3 ?

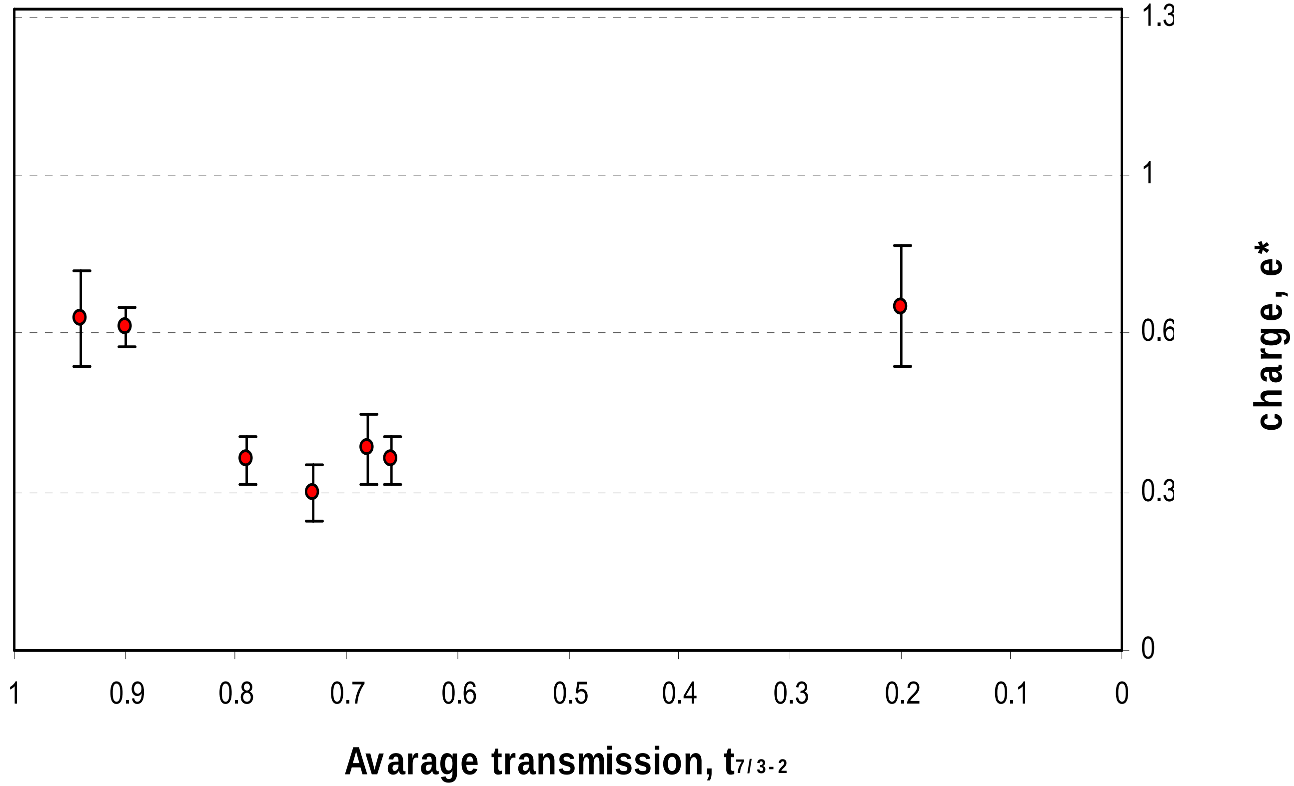
$T = 10\text{mK}$





$t_{7/3,2}$
noise x 10^{-30} (A^2/Hz)
Impinging Current, *I* (nA)
0.7e
0.33e
0.68e
0.33e
0.3e
0.4e
0.66e
0.33e
0.425e
0.2e
0.85e
0.12e

charge *vs* temperature , $\nu = 7/3$

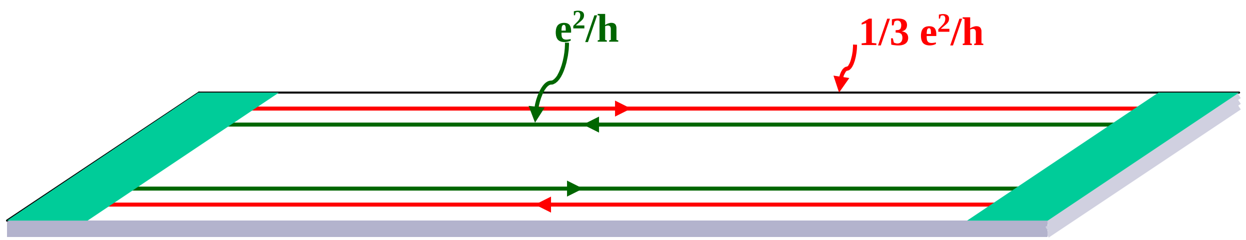


typical results: scattered charge high at both extremes of backscattering

a few preliminary results for $\nu = 2/3$

$\nu = 2/3$ without disorder

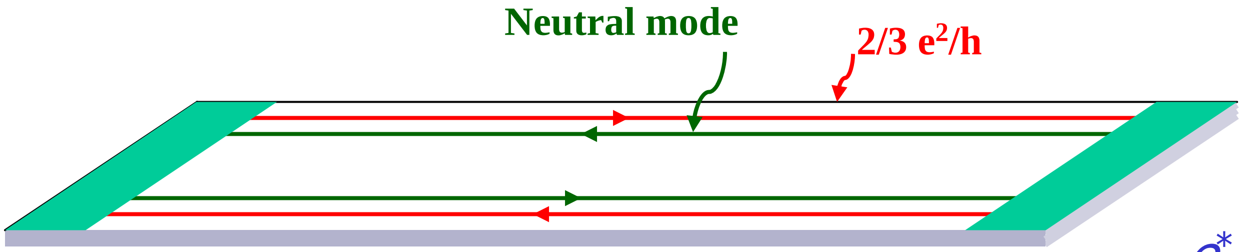
conductance > 2/3 e^2/h, depends on interaction strength



$e^* = ?$

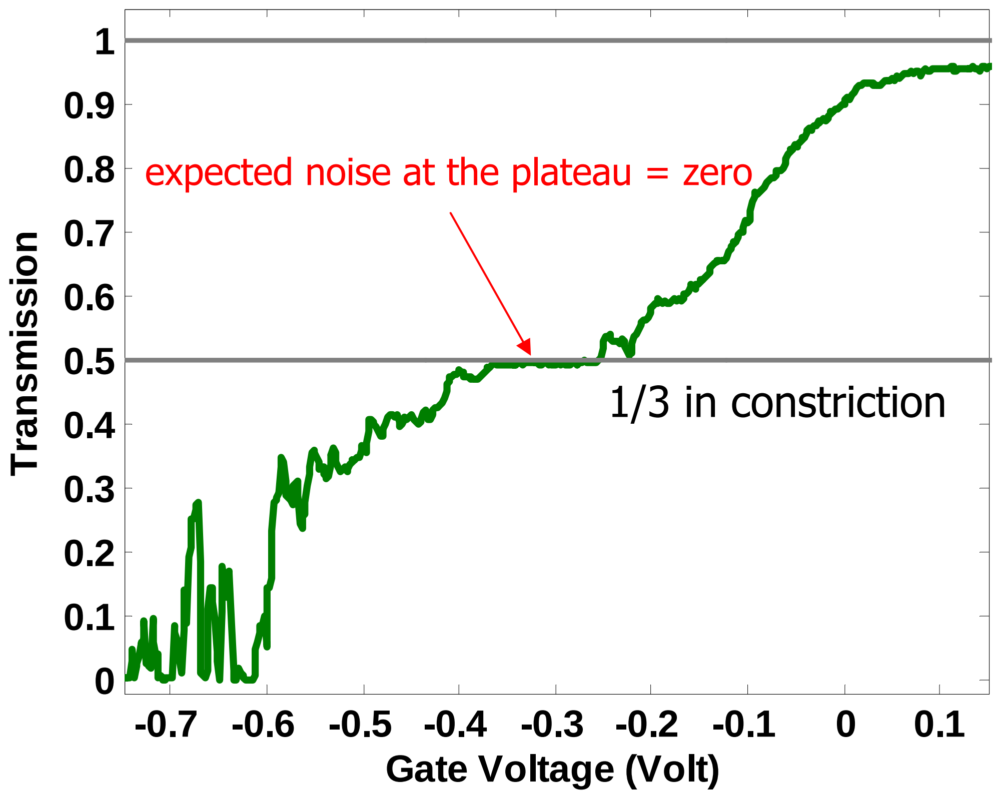
$\nu = 2/3$ with disorder (inter-channel impurity scattering)

conductance = 2/3 e^2/h, universal

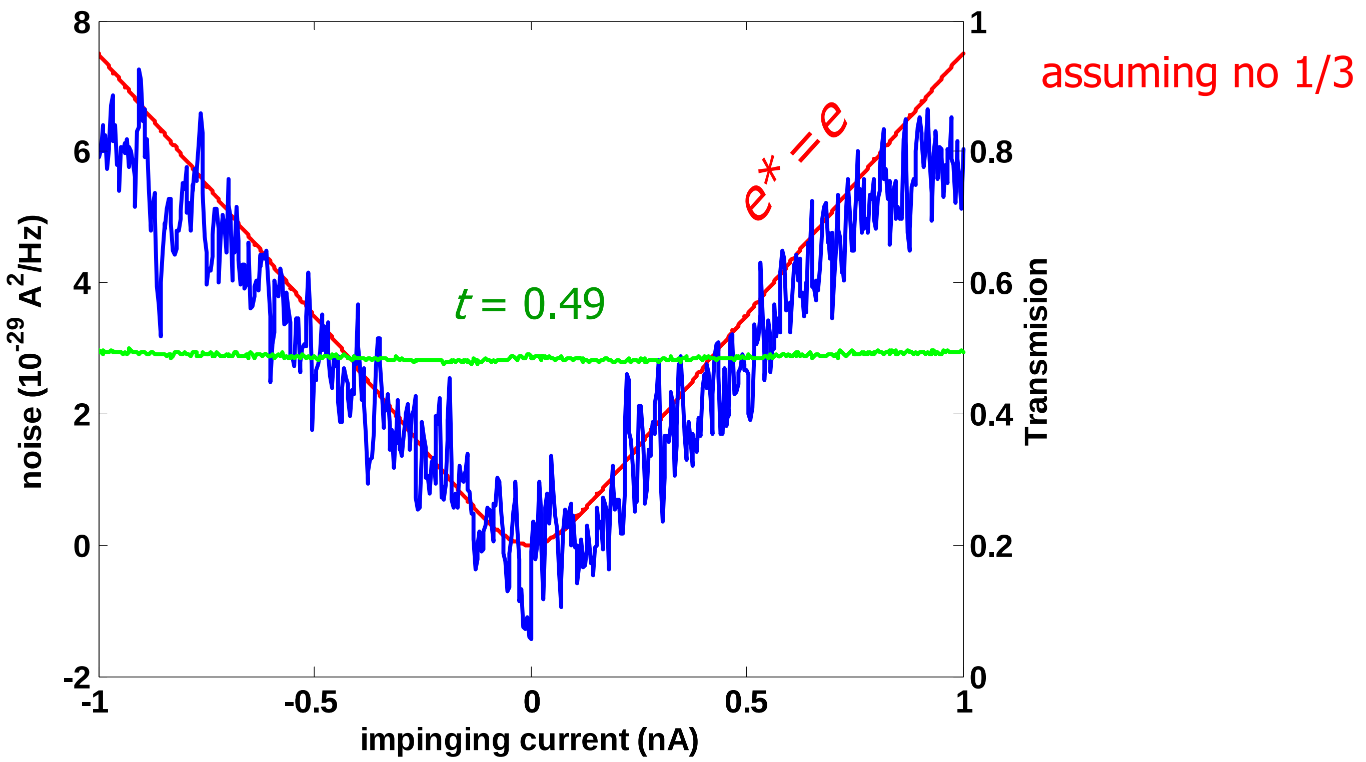


$e^* = e/3,\ 2e/3$

QPC conductance *vs* gate voltage, $\nu = 2/3$

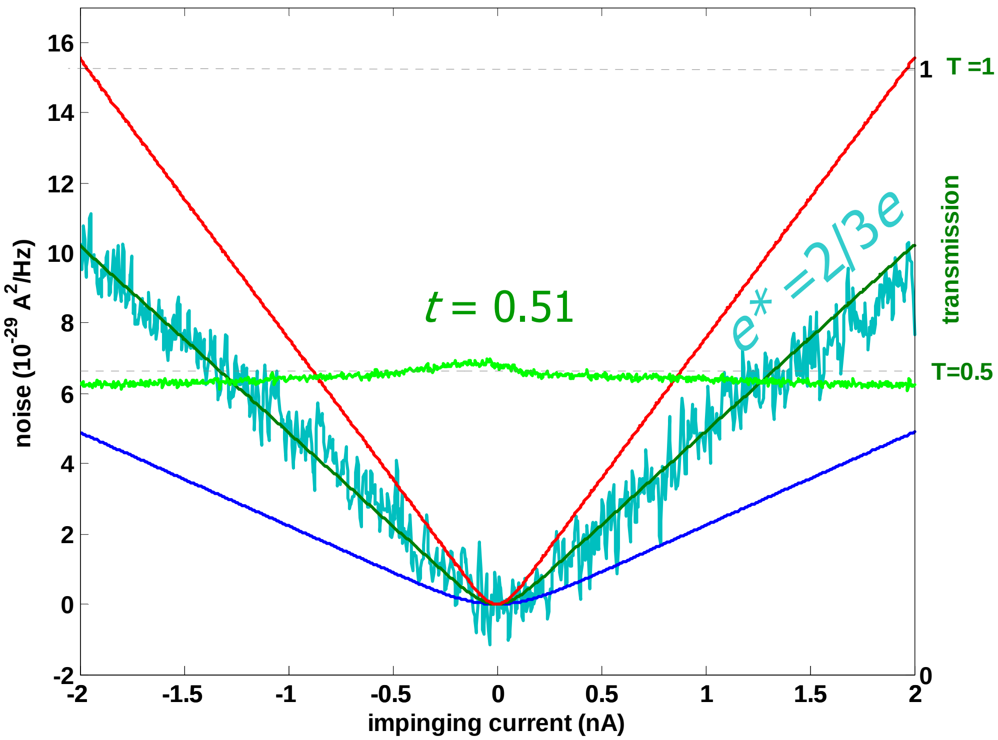


noise at the 1/3 plateau



sample # 1…….n = 1 x $10^{11}/cm^2$, μ = 4.3 X 10^6 $cm^2/V\text{-}s$ at 4K, *spacer thickness = 120nm*

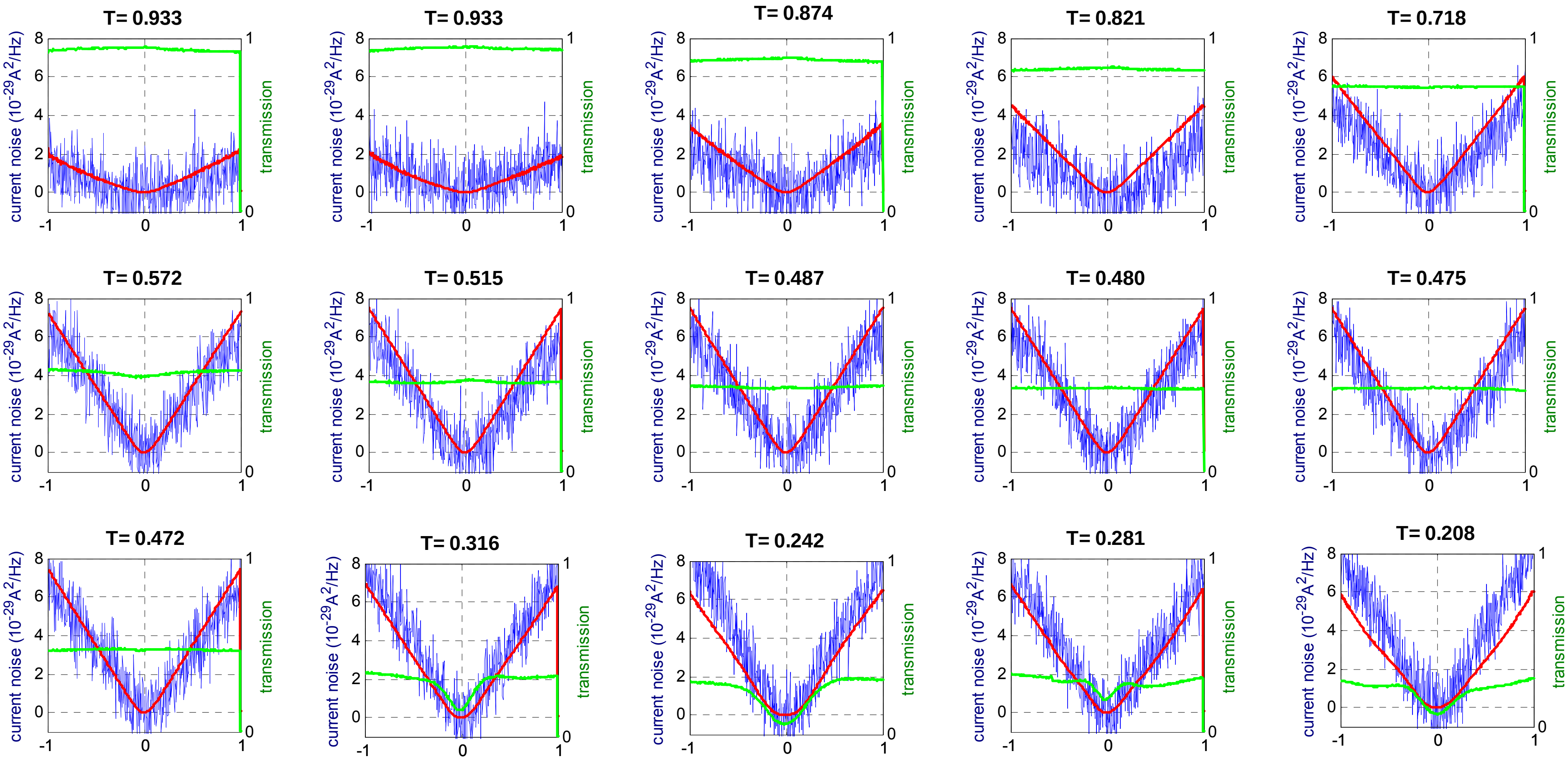
noise at the 1/3 plateau



assuming no 1/3

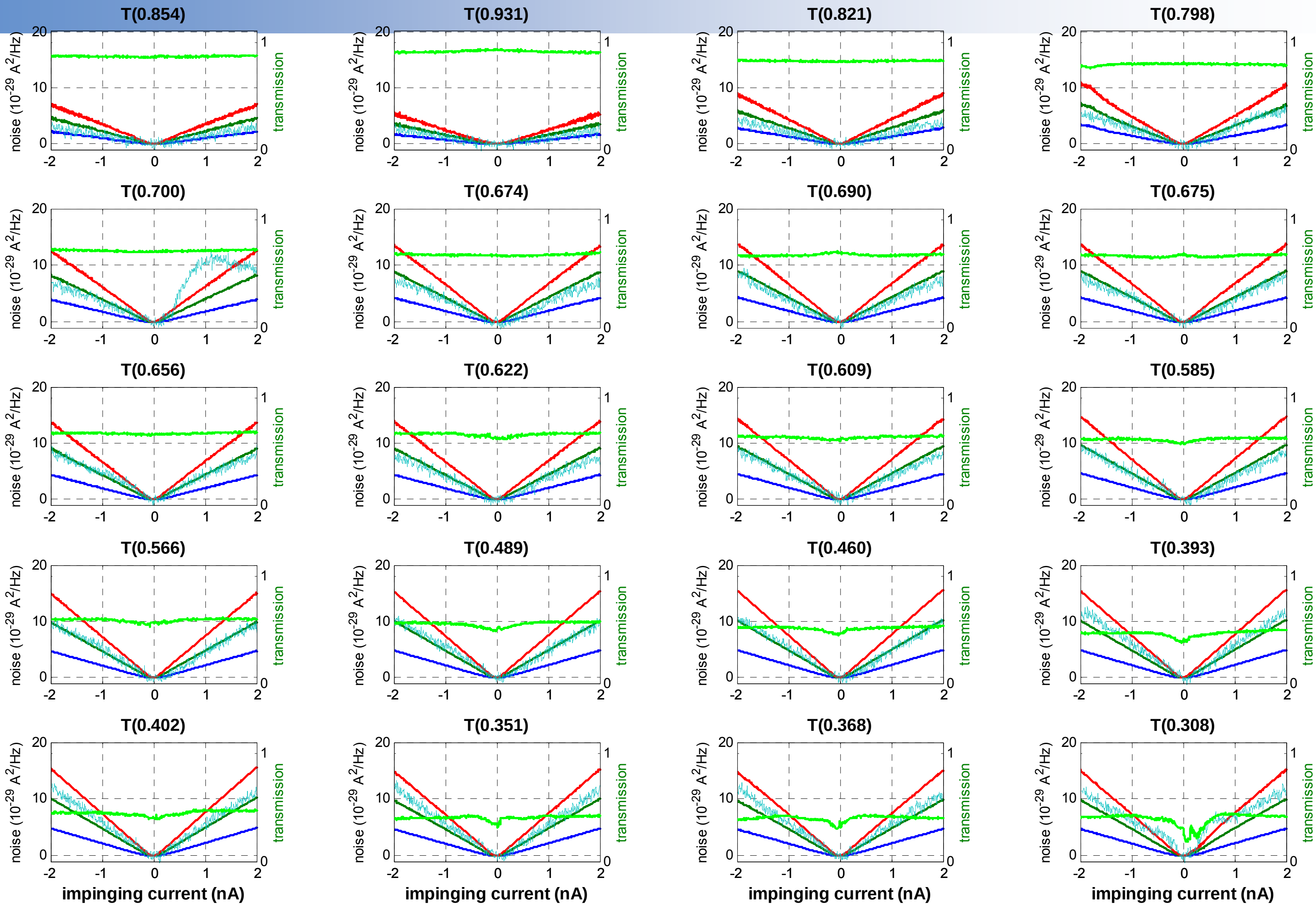
sample # 2……*n* = 0.6 X 10^{11}/cm^2, μ = 3.5 X 10^6 cm^2/V-s at 4K, *spacer thickness* = 85nm

noise at $\nu = 2/3$......sample # 1



charge $e^* = e$

noise at $\nu = 2/3$......sample # 2



charge $e^* = 2/3e$

charge at $\nu = 2/3$

initial results

why there is noise at the 1/3 plateau ?

'purer' sample .... $e^{*} = e$

'less pure' sample................. $e^{*} = 2e/3$

charge determination is not trivial

must be determined in every interference experiment